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Forecasting Research Division
Technical Report No. 95

# INCREASED SURFACE VEGETATION ROUGHNESS IN THE LIMITED AREA MODEL

by

O. Hammon and C. Wilson

MAY 1994

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## 1 Introduction

The surface winds forecast by the limited area model have been consistently too strong over land, with correspondingly large rms and direction errors, since its introduction in June 1991. The specified surface roughness values are low, typically 0.008-0.016m over the UK, being derived from a land use specified as mainly pasture and arable crops.The prototype mesoscale version of the unified model also showed this problem and before its introduction a modified surface roughness ancillary field based on the old mesoscale model's values was implemented. Roughness lengths at 10km resolution based on the work of Smith and Carson (1977) which accounted for heterogeneity and some orographic effects are used, with typical values 0.3m over lowland Britain rising to 0.5m over mountainous areas. There is a limit of 1m imposed and the roughness length for heat and moisture is specified as 1/5th of the momentum value. A comparison of recent 10m wind speed verification shows the LAM forecasts to have large biases of 2 to 2.5 m $s^{-1}$ which are largely eliminated from the mesoscale forecasts (**Fig 1.1**). There is a corresponding increase in direction errors for the LAM compared to the mesoscale model (**Fig 1.1**).

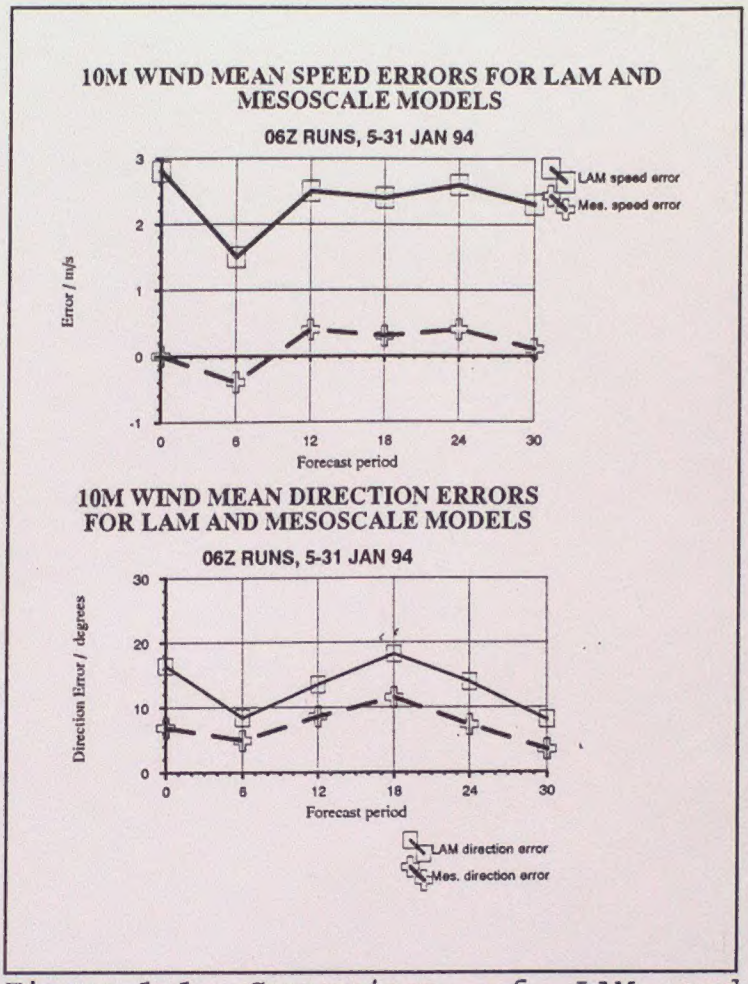


**Figure 1.1** *Comparison of LAM and Mesoscale 10m wind errors for UK land stations*

It is intended in the near future to include the effective roughness due to sub-grid scale variations in the orography. As an interim step the vegetation only values of roughness have been revised, in the light of the mesoscale experience and advice from APR division. As these values are more representative of the land use in Britain and Europe they are likely to be retained when the orographic effects are included anyway. The surface roughness currently assigned to the 24 basic land types are given in **Table 1.1**. Temperate meadow and permanent pasture, which is the dominant land cover in Britain, is assumed to be 90% short

**TABLE 1.1 SURFACE ROUGHNESS VALUES**

| Type | description | assigned value | new value |
|---|---|---|---|
| 1 | water | ****** | ******* |
| 2 | ice | $1.0 \times 10^{-4}$ | $1.0 \times 10^{-4}$ |
| 3 | inland lake | $3.0 \times 10^{-4}$ | $3.0 \times 10^{-4}$ |
| 4 | evergreen needleleaf tree | 1.00 | 1.00 |
| 5 | evergreen broadleaf tree | 1.20 | 1.20 |
| 6 | deciduous needleleaf tree | 1.00 | 1.00 |
| 7 | deciduous broadleaf tree | 1.00 | 1.00 |
| 8 | tropical broadleaf tree | 1.20 | 1.20 |
| 9 | drought deciduous tree | 1.00 | 1.00 |
| 10 | evergreen broadleaf shrub | 0.40 | 0.40 |
| 11 | deciduous shrub | 0.40 | 0.40 |
| 12 | thorn shrub | 0.40. | 0.40 |
| 13 | short grass and forbs | 0.01 | 0.12 |
| 14 | long grass | 0.04 | 0.12 |
| 15 | arable | 0.04 | 0.12 |
| 16 | rice | 0.01 | 0.12 |
| 17 | sugar | 0.08 | 0.12 |
| 18 | maize | 0.08 | 0.12 |
| 19 | cotton | 0.10 | 0.12 |
| 20 | irrigated crop | 0.04 | 0.12 |
| 21 | urban | 1.50 | 1.50 |
| 22 | tundra | 0.01 | 0.12 |
| 23 | swamp | 0.10 | 0.12 |
| 24 | soil | $3.0 \times 10^{-4}$ | $3.0 \times 10^{-3}$ |

The original values are from Buckley and Warrilow, 1988. Revised types shaded.

grass and forbs and 10% bare soil (see Jones, UMDP 70). Although the short grass and forbs category has a roughness of 0.01 m, the roughness for pasture is only ~0.008 since the roughness lengths are inversely logarithmically averaged (see UMDP 70) which increases the influence of bare soil beyond 10%. The new revised values (**Table 1.1** ) have a much increased value of 0.12m for the grasses and arable crop types to reflect the rather more inhomogeneous land use common in Britain and Europe. Large uninterrupted prairies are not found here; fields tend to be rather small with obstacles such as hedges, fences, small woods and buildings which have a significant influence on the roughness. The bare soil value has also been increased by a factor of 10. The values for tundra and swamps has also been set to 0.12m, with probably less justification in the case of tundra. The original and revised fields of surface roughness are shown in **Fig 1.2**. Most places apart from those permanently ice-covered and desert areas now have roughness values of around 0.1m or more, whereas large regions previously had values of around 0.01m. Preliminary tests showed that the revised vegetation roughness (using the same values for momentum and heat/moisture) had a beneficial impact on wind speed errors and so a full parallel suite test with the LAM was run from 20/01/94 to 8/2/94.

This note records the objective and subjective assessments of the results of the parallel suite test (sections 2 and 3). Five summer cases were also rerun to assess the impact during a different season and the subjective and objective assessments of these are given in sections 4 and 5. A summary of conclusions is given in section 6.

## 2 Objective verification

The parallel suite was configured to run the LAM only. One forecast per day to T+48 from 00UTC data time was run following reconfiguration from the global main analysis at 12UTC and four 3hour assimilation cycles.

The operational verification packages were included in the parallel suite and verification against observations and analyses was performed. Operational and trial forecasts were verified against their own analyses. Mean results for the period 21/01/94 - 07/2/94 were obtained for the whole area (code 888) for verification against analyses and the smaller areas (codes 88 and 5) shown in **Fig 2.1**, for both verification against analyses and observations. The results were very similar for all areas and those for areas 888 and 88 will

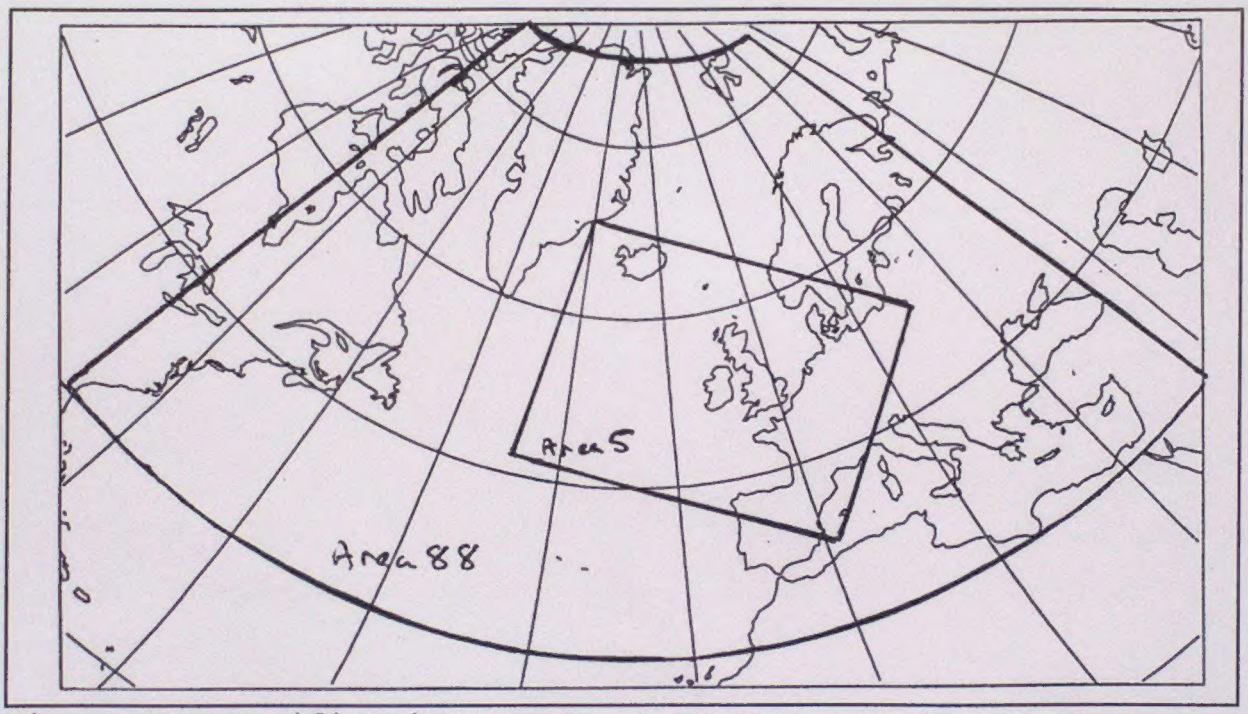


**Figure 2.1** *Verification areas*

mainly be shown here. The verification times were T+0, +24, +48 for verification against observations and T+24, +48 for verification against analyses. To sample the diurnal cycle verification every 6h would have been desirable and this will be included in future parallel suite trials of the LAM. Inclusion of a second forecast from 12UTC would also be useful and should be included if resources allow. Despite these drawbacks the parallel trial shows a clear and consistent beneficial impact as shown below.

The bias of the 10m wind speed over land was reduced by 0.8 kt at T+0 and by over 1 kt at T+24 (**Fig 2.2**) in area 88. There was a smaller reduction of ~0.3 kt over sea (and coastal) stations with a mean reduction over all stations of ~0.7-0.8 kt for the analyses and forecasts (**Fig 2.2**). The rms vector wind error at 10m was also less for the increased roughness trial by 5-7% over land and ~4% for all observations (**Table 2.1**).
The negative bias of mean sea-level pressure was reduced in the trial version for the forecasts at T+24,T+48 by 0.1hPa and 0.2hPa respectively ( **Fig 2.3** ) and the rms errors

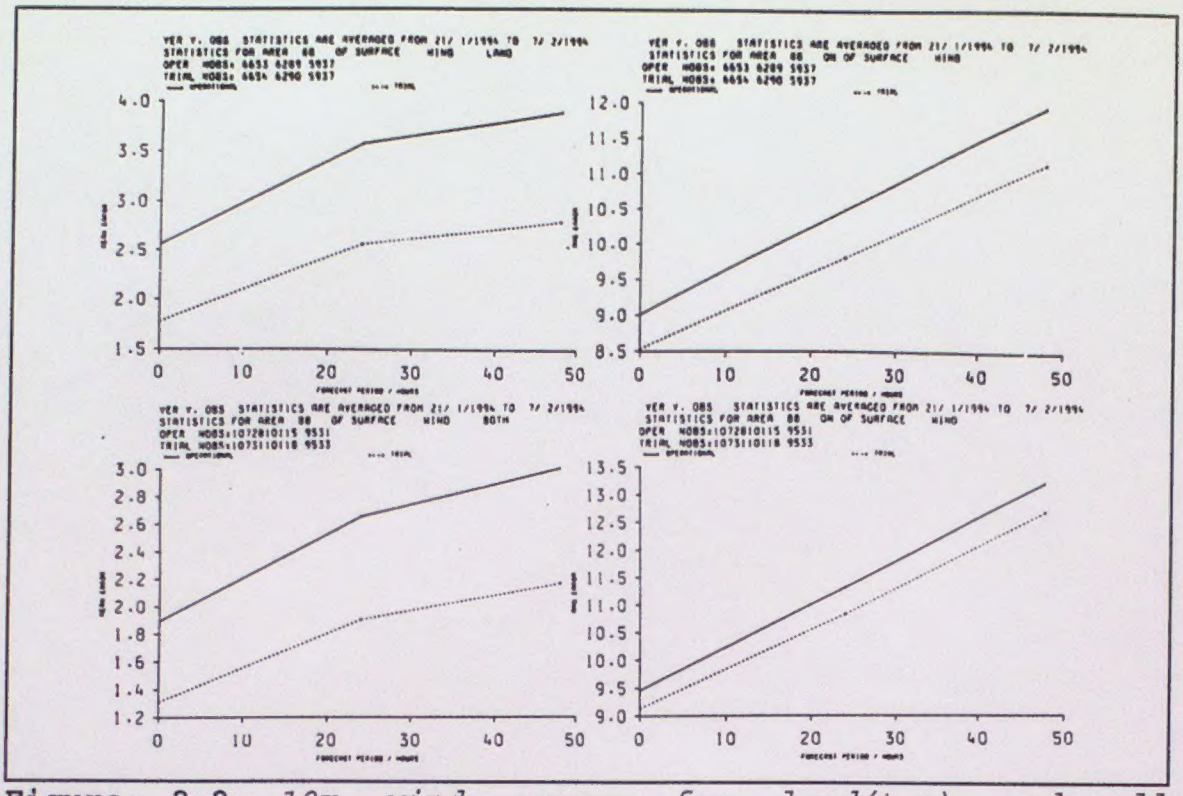

**Figure 2.2** *10m wind errors for land(top) and all points(bottom); mean speed(left) and rms vector wind (right). Verified against observations*

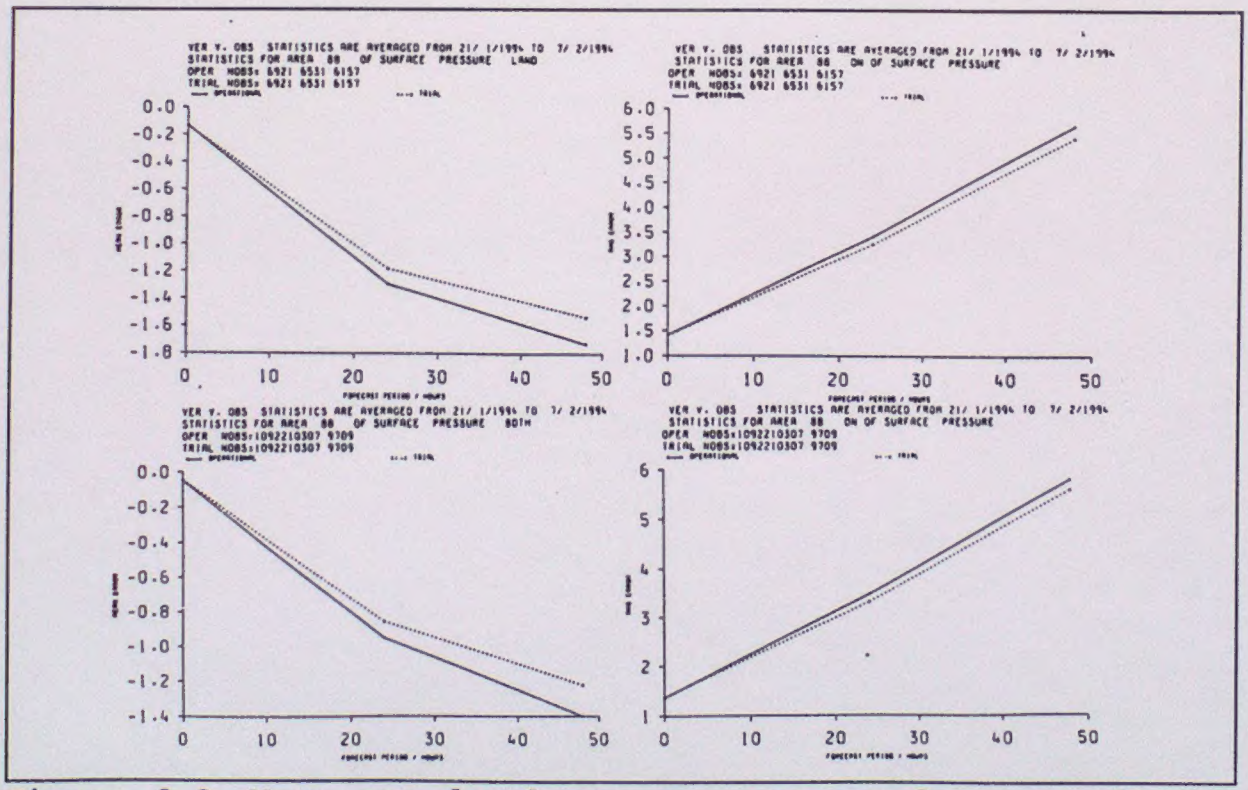

**Figure 2.3** *Mean sea level pressure errors for area 88 for land(top) and all points (bottom); mean bias(left), rms (right)*

were reduced by ~4% ( **Table 2.1** ). Similar reductions were found for the verification against analyses for the whole LAM domain.

The improved winds were not confined to the surface. The overstong wind speed at 850hPa was reduced by 0.2 kt and 0.4 kt at T + 2 4 , T + 4 8 respectively. Similarly at 500hPa the error was reduced by ~0.1 kt and ~0.2 kt. Smaller but non-negligible reductions were found at higher levels (**Fig 2.4**).Rms forecast errors improved by 1 to 2% at 850hPa and ½ to 1% at 500hPa with smaller reductions generally elsewhere at higher levels ( **Tables 2.2, 2.3** ). Overall there is a general improvement to most wind scores with most impact at 850hPa.

| | PMSL %RMS CHANGE (TRIAL-OPER) | | |
|---|---|---|---|
| | VERIFICATION AGAINST OBSERVATIONS | | |
| | T+0 | T+24 | T+48 |
| AREA 5 LAND | 0.0 | -3.6 | -3.5 |
| AREA 5 SEA | 1.4 | -2.5 | -1.7 |
| AREA 5 BOTH | 0.0 | -2.9 | -2.3 |
| AREA 88 LAND | -0.4 | -4.7 | -4.4 |
| AREA 88 SEA | 0.0 | -3.1 | -2.3 |
| AREA 88 BOTH | 0.4 | -4.5 | -3.6 |
| | | | |
| | 1.5m TEMP %RMS CHANGE (TRIAL-OPER) | | |
| | VERIFICATION AGAINST OBSERVATIONS | | |
| AREA 5 LAND | 1.2 | 0.2 | -1.1 |
| AREA 5 SEA | 0.4 | -1.7 | 0.3 |
| AREA 5 BOTH | 1.0 | -0.3 | 0.1 |
| AREA 88 LAND | -0.9 | -0.9 | -0.5 |
| AREA 88 SEA | -0.2 | -0.3 | -0.2 |
| AREA 88 BOTH | 0.0 | -0.4 | -0.2 |
| | | | |
| | 10m WIND %RMS CHANGE (TRIAL-OPER) | | |
| | VERIFICATION AGAINST OBSERVATIONS | | |
| AREA 5 LAND | -8.4 | -8.1 | -7.5 |
| AREA 5 SEA | -0.6 | -0.5 | -0.6 |
| AREA 5 BOTH | -3.7 | -3.5 | -3.0 |
| AREA 88 LAND | -5.3 | -6.6 | -6.7 |
| AREA 88 SEA | -1.1 | -1.4 | -1.3 |
| AREA 88 BOTH | -3.4 | -4.3 | -4.0 |

TABLE 2.1

**Height errors**

The improved surface pressure also leads to improved height errors. The bias and rms are generally improved by ~2m at T+48 (**Fig 2.5**). The greatest improvement in rms errors is at 850hPa, being 5% for verification against observations ( **Table 2.2** ) and ~3% when verified against analyses ( **Table 2.3** ). These are quite significant improvements; potential further improvements from a proper treatment of orographic roughness may be anticipated.

**Temperatures**

There was a slight worsening of the cold temperature bias which was most evident for the land only verification (**Fig 2.6**). However the increase cooling was only ~0.02K at T+48 for most levels with a maximum change at 250hPa of 0.05K. Despite the slight degradation in mean temperatures, rms errors were generally slightly better for the trial by typically 0.7% with the largest improvement at T+24 for the 850hPa temperature of 1.7% for area 88. ( **Table 2.2** ). Verification against analyses was very similar and again rms errors were generally slightly improved by the trial with the largest improvement at T+24 for the 850hPa temperature of 1.3% ( **Table 2.3** ). Again the overall assessment is favourable to the trial.

| HEIGHT %RMS CHANGE (TRIAL-OPER) | | | | WIND %RMS CHANGE (TRIAL-OPER) | | | |
|---|---|---|---|---|---|---|---|
| VERIFICATION AGAINST OBSERVATIONS | | | | VERIFICATION AGAINST OBSERVATIONS | | | |
| AREA 5 | T+0 | T+24 | T+48 | AREA 5 | T+0 | T+24 | T+48 |
| 850.0 | 0.0 | -3.8 | -3.1 | 850.0 | -0.5 | -1.9 | -1.6 |
| 500.0 | 0.0 | -3.3 | -2.6 | 500.0 | -0.1 | -1.7 | -0.4 |
| 300.0 | -0.3 | -2.1 | -1.4 | 300.0 | -0.2 | -0.8 | 0.0 |
| 250.0 | 0.0 | -1.4 | -1.6 | 250.0 | -0.2 | -0.5 | -0.2 |
| 200.0 | 0.3 | -1.3 | -1.4 | 200.0 | -0.1 | -0.6 | -0.3 |
| 100.0 | 0.2 | -0.7 | -1.3 | 100.0 | -0.1 | -0.5 | -0.8 |
| AREA 88 | | | | AREA 88 | | | |
| 850.0 | 0.0 | -4.2 | -5.3 | 850.0 | 0.6 | -1.7 | -1.4 |
| 500.0 | 0.0 | -3.9 | -2.8 | 500.0 | -0.3 | -1.1 | -0.8 |
| 300.0 | -0.2 | -2.0 | -2.1 | 300.0 | -0.3 | -0.8 | -0.1 |
| 250.0 | 0.0 | -1.8 | -2.2 | 250.0 | -0.1 | -0.4 | -0.2 |
| 200.0 | 0.0 | -0.9 | -1.7 | 200.0 | -0.3 | -0.6 | -0.2 |
| 100.0 | -0.2 | -1.0 | -1.2 | 100.0 | 0.5 | -0.2 | -0.5 |
| | | | | | | | |
| TEMP %RMS CHANGE (TRIAL-OPER) | | | | REL HUM %RMS CHANGE (TRIAL-OPER) | | | |
| VERIFICATION AGAINST OBSERVATIONS | | | | VERIFICATION AGAINST OBSERVATIONS | | | |
| AREA 5 | T+0 | T+24 | T+48 | AREA 5 | T+0 | T+24 | T+48 |
| 850.0 | 0.0 | -1.4 | -0.8 | 850.0 | -0.2 | -1.2 | -0.8 |
| 500.0 | 0.0 | -0.7 | 0.8 | 700.0 | 0.5 | -1.1 | -0.4 |
| 300.0 | 0.0 | -0.4 | 0.2 | 500.0 | -0.1 | -0.4 | -0.4 |
| 250.0 | 0.5 | -0.8 | 0.3 | AREA 88 | | | |
| 200.0 | -0.3 | -0.7 | -0.2 | 850.0 | -0.1 | -0.9 | -0.7 |
| 100.0 | 0.4 | -0.7 | 0.1 | 700.0 | 0.1 | -0.7 | -0.7 |
| AREA 88 | | | | 500.0 | -0.1 | -0.4 | -0.4 |
| 850.0 | -1.0 | -1.7 | -0.8 | | | | |
| 500.0 | 0.0 | -0.1 | 0.5 | | | | |
| 300.0 | 0.0 | 0.0 | -0.6 | | | | |
| 250.0 | 0.0 | -0.7 | -0.7 | | | | |
| 200.0 | 0.0 | -0.4 | -0.7 | | | | |
| 100.0 | 0.0 | -0.4 | -0.8 | | | | |

**TABLE 2.2**

| HEIGHT RMSE %CHANGE (TRIAL-OPER) | | | WIND RMSE %CHANGE (TRIAL-OPER) | | |
|---|---|---|---|---|---|
| VERIFICATION AGAINST ANALYSES | | | VERIFICATION AGAINST ANALYSES | | |
| AREA 5 | T+24 | T+48 | AREA 5 | T+24 | T+48 |
| 850 | -2.1 | -1.8 | 850 | -0.9 | -1 |
| 500 | -1.9 | -1.1 | 500 | -0.5 | -0.3 |
| 300 | -1.1 | -0.9 | 300 | -0.2 | 0.1 |
| 250 | -1.1 | -0.9 | 250 | -0.1 | 0.1 |
| 200 | -1.2 | -1.4 | 200 | -0.3 | -0.1 |
| 100 | -1.4 | | 100 | -0.3 | |
| AREA 88 | T+24 | T+48 | AREA 88 | T+24 | T+48 |
| 850 | -2.8 | -2.6 | 850 | -1.1 | -1.2 |
| 500 | -1.8 | -2 | 500 | -0.7 | -0.6 |
| 300 | -1 | -1.3 | 300 | -0.3 | -0.2 |
| 250 | -1 | -1.3 | 250 | -0.1 | -0.1 |
| 200 | -1.1 | -1.3 | 200 | -0.3 | -0.1 |
| 100 | -0.7 | | 100 | -0.3 | |
| AREA 888 | T+24 | T+48 | AREA 888 | T+24 | T+48 |
| 850 | -2.6 | -2.9 | 850 | -1.2 | -1.3 |
| 500 | -1.8 | -1.9 | 500 | -0.5 | -0.6 |
| 300 | -1.1 | -1.2 | 300 | -0.3 | -0.3 |
| 250 | -0.7 | -1 | 250 | -0.2 | -0.2 |
| 200 | -0.8 | -1.1 | 200 | -0.2 | -0.3 |
| 100 | -0.4 | | 100 | -0.4 | |
| | | | | | |
| TEMP RMSE %CHANGE (TRIAL-OPER) | | | REL HUM RMSE %CHANGE (TRIAL-OPER) | | |
| VERIFICATION AGAINST ANALYSES | | | VERIFICATION AGAINST ANALYSES | | |
| AREA 5 | T+24 | T+48 | AREA 5 | T+24 | T+48 |
| 850 | -0.7 | -0.9 | 950 | -0.4 | -0.7 |
| 500 | 0 | 0 | 850 | -0.6 | -0.6 |
| 300 | -0.6 | 0.4 | 700 | -0.2 | 0 |
| 250 | -0.5 | 0 | 500 | -0.2 | -0.1 |
| 200 | 0 | 0 | AREA 88 | T+24 | T+48 |
| 100 | 0 | | 950 | -0.5 | -0.7 |
| AREA 88 | T+24 | T+48 | 850 | -0.6 | -0.6 |
| 850 | -0.6 | -0.8 | 700 | -0.4 | -0.1 |
| 500 | 0 | -0.5 | 500 | -0.2 | -0.1 |
| 300 | -0.7 | -0.5 | AREA 888 | T+24 | T+48 |
| 250 | 0 | -0.4 | 950 | -0.8 | -0.8 |
| 200 | -0.6 | -0.4 | 850 | -0.5 | -0.5 |
| 100 | 0 | | 700 | -0.4 | -0.3 |
| AREA 888 | T+24 | T+48 | 500 | -0.2 | -0.1 |
| 850 | -1.3 | -0.8 | | | |
| 500 | 0 | 0 | | | |
| 300 | -0.7 | -0.5 | | | |
| 250 | -0.6 | -0.8 | | | |
| 200 | 0 | -0.4 | | | |
| 100 | -1 | | | | |

**TABLE 2.3**

**Relative humidity**

The mean bias was slightly greater for the increased roughness trial version, with maximum increases of ~0.3% relative humidity at 850hPa (**Fig 2.7**). Rms results were slightly better for the trial however with generally decreases of ~0.5-1% in the errors ( **Tables 2.2 ,2.3** ).

**Surface temperature**

The mean cold bias was generally slightly better for the larger area (88) although the smaller area (5) was worse. The rms errors were generally little different **(Table 2.1** ) , mostly slightly better for the trial except in area5 over land at T+0, T+24.

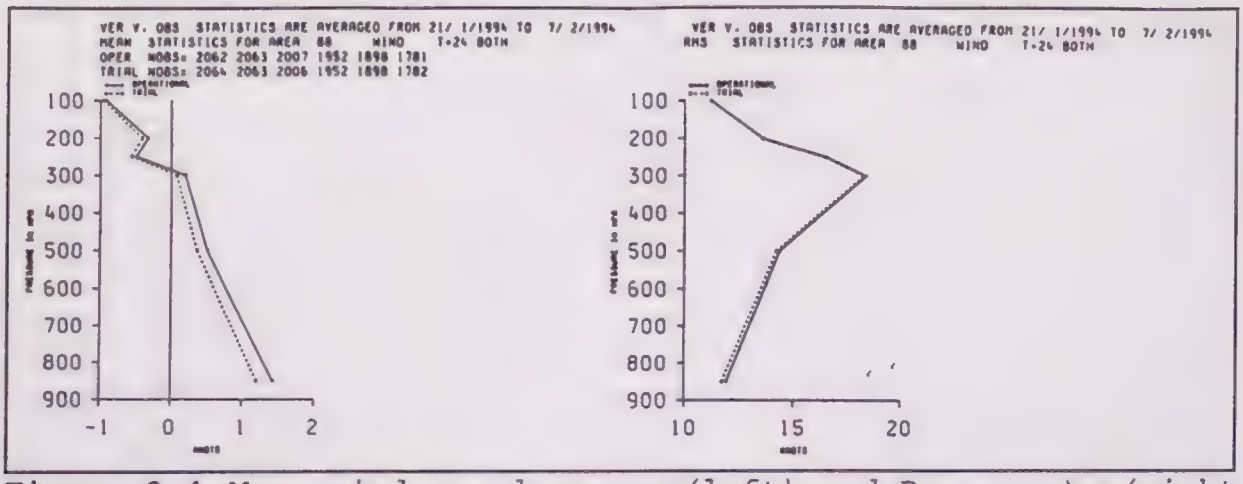


**Figure 2.4** *Mean wind speed errors (left) and Rms errors (right )for area 88 at T+24. Verified against observations.*

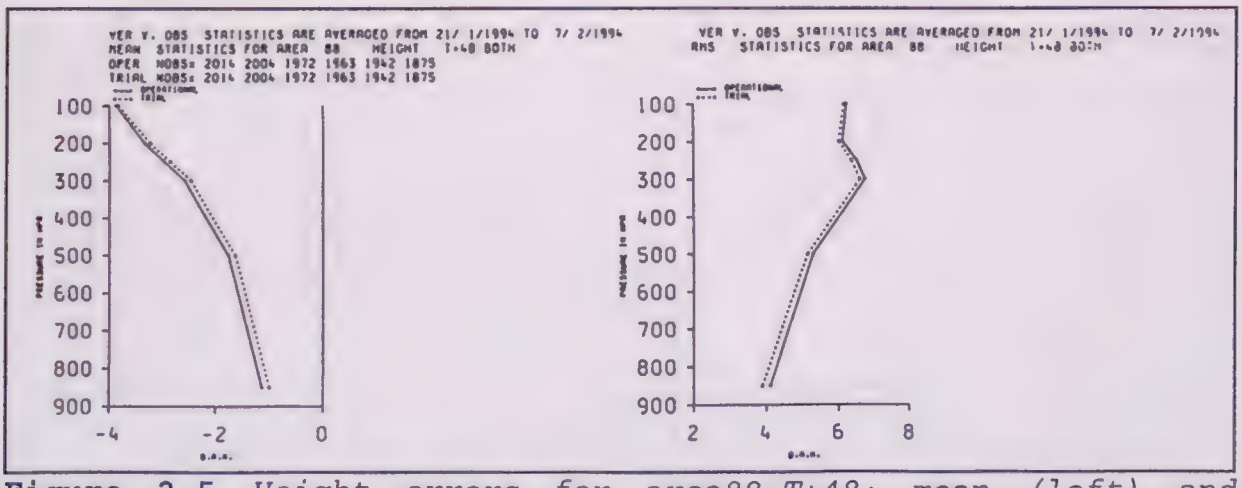


**Figure 2.5** *Height errors for area88,T+48; mean (left) and rms(right).Verification against observations.*

The overall objective assessment is overwhelming in favour of the trial. The improved surface winds which were the aim of the change have been obtained. In addition there are beneficial improvements in most parameters throughout the troposphere and particularly in the lower half.

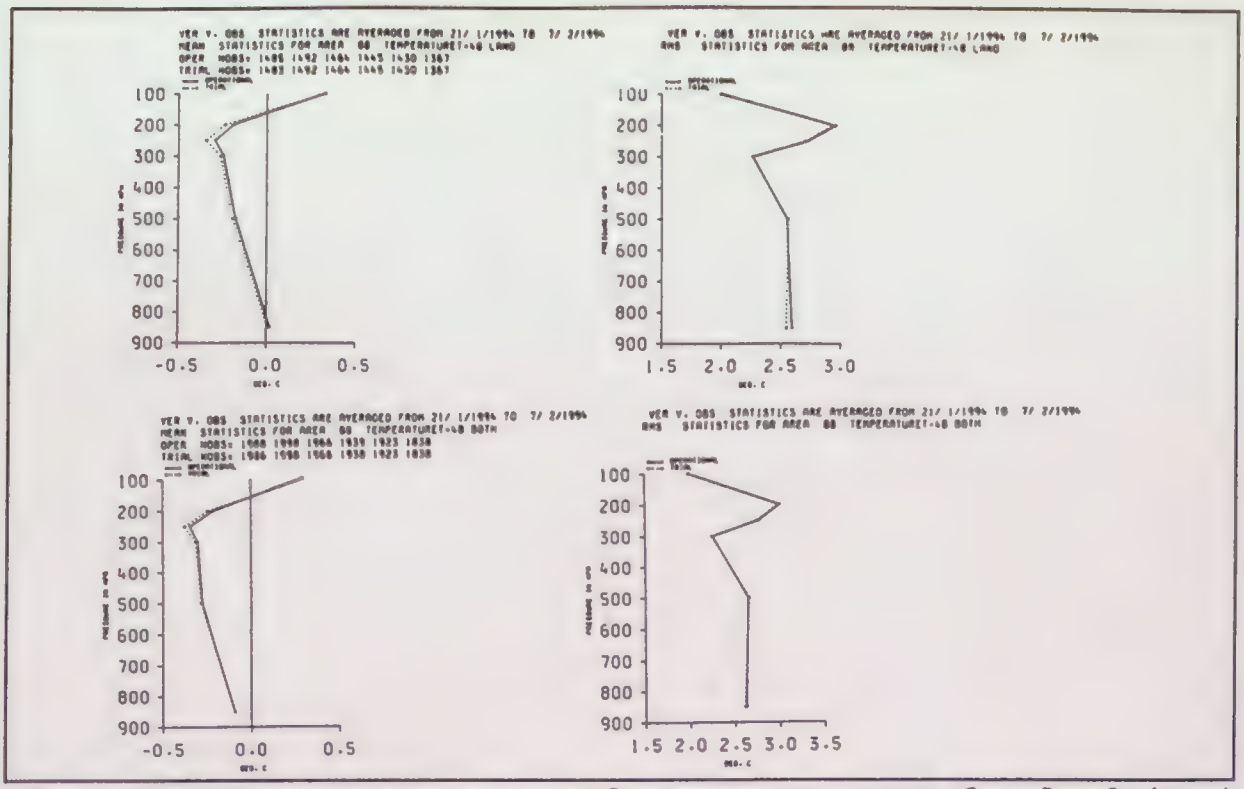


**Figure 2.6** *Temperature errors for area 88, T+48 for land (top) and all points(bottom); mean(left) and rms(right). Verification against observations.*

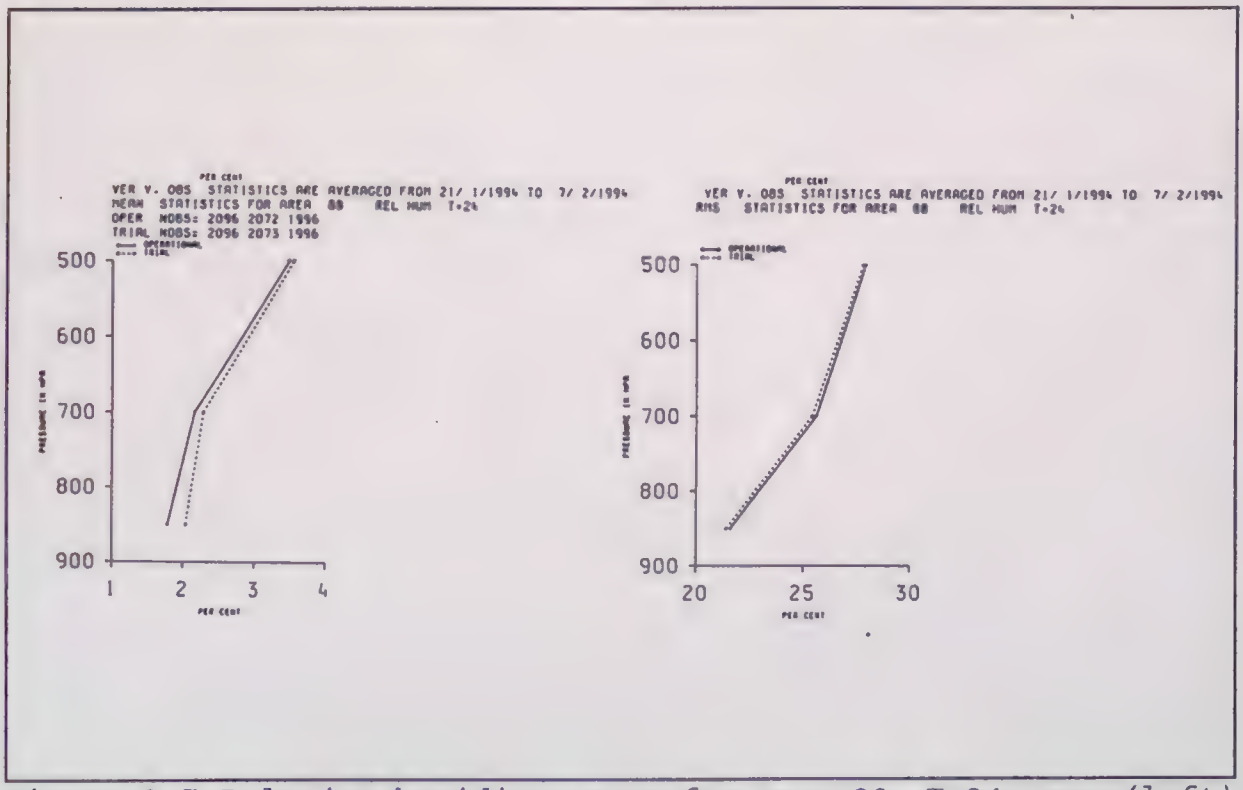


**Figure 2.7** *Relative humidity errorsfor area 88, T+24; mean(left) and rms(right). Verified against sonde observations.*

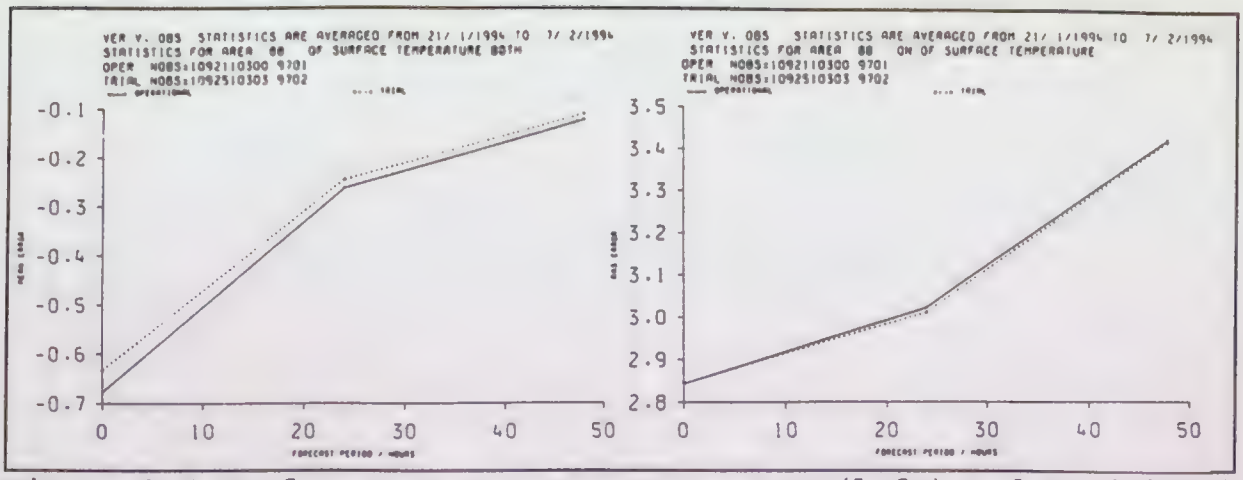


**Figure 2.7** *Surface temperature errors; mean(left) and rms(right)*

## 3. Subjective Assessment of the Impact of Increased Vegetation Roughness on Limited Area Model Forecasts.

Trial period 20/01/94 - 08/02/94

### 3.1 Introduction.

Trial forecasts up to T+48 showing 10m winds,mean sea level pressure,rainfall,cloud,500mb height,250mb winds and surface temperature were compared with operational forecasts and assessed. In general, differences were very small and no changes of evolution occurred. The main impact of the increased vegetation roughness was noticed in the reduction of 10m wind speeds and a slight filling of depressions over land only.

### 3.2 Case Studies from the Parallel Suite Trial

a) DT00Z 26/01/94

Gale force west to northwesterly winds were the main feature of the weather over the British Isles during the 27/28th January. The wind observations for 00Z on the 28th, **Figure 3.1**, shows steady winds of 30-40 knots, gusts 40-50 on exposed coasts and over high ground in the north. Even inland winds reached 15-25 knots with gusts 30-40.

The operational T+48 mean sea level forecast, verifying at 00Z 28th January, **Figure 3.2a**, predicted the strong northwesterly over the British Isles well, but the predicted mean sea level pressure was too low and the gradient too strong. The observed pressure range was 992 - 1024mb, whereas the predicted range was 972 - 1016mb. The trial forecast, **Figure 3.2b**, was almost identical, with the difference map, **Figure 3.3b**, indicating that the trial pressure was just 0.5mb higher over the British Isles.

The forecast surface winds for T+48, verifying at 00Z 28th January, from the operational and trial forecasts are compared in **Figures 3.4a,b** respectively. Some reductions in the trial forecast wind speed over land can be seen over the British Isles and also over Europe. The easterly wind vector differences shown in **Figure 3.3a** over land indicate a reduction in the predicted westerly wind component of 5-10 knots in the trial forecast. The

reduced wind speeds inland were more realistic, even allowing for the forecast error in the strength of the gradient over the British Isles.

b)DT00Z 03/02/94

At 00Z 4th February, a very deep depression, centre 957mb, was centred over Western Ireland, with strong or gale force east to southeasterly winds over the British Isles. The observations, **Figure 3.5**, show that the recorded wind speeds reached gale force over exposed coasts and hills in Northern England and Scotland with gusts 40 to 50. Gale force winds were also reported in exposed parts of Devon and Cornwall. Over East Wales,Midlands and Southeast England, winds were lighter, generally 15 to 20 knots with gusts 35.

The operational T+24 mean sea leval pressure forecast, **Figure 3.6a**,was a good forecast, although the depression was predicted slightly too deep at 951mb and slightly too far southeast, over Cork rather than Western Ireland. The trial forecast, **Figure 3.6b**, was almost identical, but the mean sea level difference chart, **Figure 3.7b**, indicates the trial centre to be 1mb higher.

The T+24 forecast surface winds around the depression from the operational and trial forecasts are compared in **Figures 3.7a** and **3.7b** respectively. Both forecasts predict gale force surface winds of 30-40 knots over Scotland, Northern England, Wales and Southwest England. In general, the forecast winds are too strong, especially over England and Wales. Inland, the trial winds are about 5 knots lighter. The differences in the operational and trial surface winds are highlighted in the vector difference chart, **Figure 3.8a**. The northerly wind vector differences over England indicate a reduction in the trial southerly winds of 4-8 knots over East wales and the Midlands. The lighter trial winds are closer to the observed winds.

c)DT00Z 04/02/94

A comparison of the operational and trial mean sea level pressure forecasts for T+48,verifying at 00Z 6/2/94, in **Figures 3.9a** and **3.9b** respectively, shows a noticeable difference in the depth of a depression over Southeast Russia, with the operational depression being 4mb deeper. C.F.O. analysed the centre of the depression as 995mb, so the trial forecast was an improvement. Marked differences in the surface wind forecasts around the depression are indicated in the vector wind difference chart, **Figure 3.10a**. The clockwise direction of the difference vectors indicate a weakening of the surface wind flow flow around the depression in the trial forecast. The forecast speed and direction of the surface winds around the centre of the depression are compared in **Figures 3.10b** and **3.10c**. In particular, the strong southerly winds to the east of the depression are 10 knots lighter in the trial forecast, **Figure 3.10c**, as are the strong northerly winds west of the centre.There were insufficent observations near the centre of the depression to verify these wind forecasts.

d)DT00Z 05/02/94

The operational and trial mean sea level pressure forecasts at T+48, verifying at 00Z 7/2/94, are compared in **Figures 3.11a** and **3.11b** respectively. These charts show that differences in the forecasts were hard to find even at T+48 and that there were no changes in evolution. However there were small differences developing in two depressions, one over Newfoundland and one over Siberia.

The forecast differences between the T+48 forecast mean sea level pressure and surface wind speeds over Newfoundland are highlighted in **Figures 3.12a** and **3.12b**. The mean sea level difference chart, **Figure 3.12a**, indicates a difference of 3-4mb in the depth of the depression over Newfoundland, with the operational depression being deeper. Both forecast depressions were much too deep, so the trial depression, being less deep, verified better. C.F.O. analysed two centres, one at 993mb just north of Newfoundland and a deeper centre, 986mb, at 50N 45W. The direction of the predicted surface winds for T+48 are indicated by the vector wind arrows in **Figure 3.13**. This particular forecast comes from the trial forecast but the operational forecast was very similar. The vector wind differences shown in **Figure 3.12b**, indicate a weakening of the surface winds around the depression in the trial forecast, with the greatest impact on the southeasterly winds just to the east of the centre.

The 6mb difference in mean sea level pressure over Siberia, shown in **Figure 3.14a**, is associated with the depression at 55N 65E. The operational forecast has a more complex centre, with the southern portion being deeper than in the trial forecast. The wind vector differences, **Figure 3.14b**, indicate a reduction in the westerly wind components over Europe in the trial forecast with a weakening of the surface winds around the depression.

### 3.3 Mean Changes

The surface wind and mean sea level forecasts were meaned over the trial period,(20/1/94 - 8/2/94), for both the trial and operational forecasts.

**Figure 3.15** shows the impact of increased vegetation roughness on the mean sea level pressure and 10m wind analyses. Mean sea level differences, **Figure 3.15a**, were very small, indicating a tendency for the trial pressure to be slightly higher over land but only by 0.1mb. This minimal impact is confirmed by comparing the operational and trial analyses in **Figures 3.16a,b** respectively. The 10m wind analyses in **Figures 3.17a,b** show a predominantly westerly flow over North America, the Atlantic and Europe, with the strongest winds in the east Atlantic. The wind vector difference chart, **Figure 3.15b**, shows a noticeable impact over Europe. The easterly vectors indicate a reduction in the westerly component of 0.5-1.0 m/s over Western Europe, with the largest differences being a 2.5 m/s reduction in the strong southerly flow over Siberia.

The impact of the increased vegetation roughness on mean sea level pressure increased with time during the forecast. This can be confirmed by comparing **Figures 3.18a,19a and 20a**. The maximum impact at T+48,**Figure 3.20a**, is a mean 1.0mb at 55N 65E, associated with the filling of old depressions in this region. Pressure was slightly higher over land in the trial forecasts but over the U.K. the mean increase at T+48 was only 0.2mb.

The impact of increased vegetation roughness on the 10m winds during the forecast resulted in a noticeable reduction in windspeed which was beneficial. At T+48, the impact is shown by the reduction in the westerly flow over Europe and in the strong southerly flow over Siberia. Over the U.K., at T+48, the difference amounts to a reduction of 1m/s in the mean wind speed of 6m/s.

## 4 The Impact of Increased Vegetative Roughness on Summer Cases

Five cases, (DT 00Z 10/5/93, DT 00Z 3/7/93, DT 00Z 5/7/93, DT 00Z 9/7/93, DT 00Z 25/7/93), were chosen to test the impact of the increased vegetative roughness on winds and surface heat and moisture fluxes in summer forecasts. Each case was rerun using trial and current operational versions with version 3.2 and a 12-hour assimilation cycle. Both versions used the available operational acobs files. Brief details of the main differences noted are given below.

a)Mean sea level pressure

A very slight impact at T+36/48 was noticed overland, with depressions 1-2mb less deep in the trial forecasts. No changes in evolution occurred. The RMS errors shown in the objective verification section (Section 5a) was very slightly in favour of the trial forecasts.

b)Precipitation

Essentially the precipitation was unchanged. However, in one case, DT00Z 9/7/93, a difference was noticed in the intensity of showers forecast over East Anglia, Essex and Kent at T+36. The trial version predicted heavy showers from convective depth 20,000-29,000 feet in this region, whereas the operational forecast predicted lighter showers from convective depth 10,000-14,000 feet. At the verifying time of 12Z 10/07/93 the reported showers were light, although heavy showers with isolated thunderstorms were reported later between 15Z and 18Z.

c) Wind

The most noticeable impact of the increased vegetative roughness was seen in the slight reduction in forecast wind speeds over land. Strong winds overland were 5 knots lighter in the trial forecasts and, in most cases, fitted the observed winds better. The decrease in wind speeds overnight was also better predicted by the trial version.

Differences in the forecast surface X/Y stresses over Scotland in strong westerly winds amouted to 0.1-0.2 newtons/$m^2$. The RMS errors shown in the objective verification, Section 5c, were in favour of the trial wind forecasts with a 2-3% advantage at levels 1 and 2.

d) Surface sensible heat fluxes

The trial forecasts predicted higher surface sensible heat fluxes and lower surface temperstures over land at midday. Maximum differences of 100-200 w/$m^2$ (20% increase) in the fluxes were seen over North Africa in the Libyan desert.Over Europe, differences were much smaller, with a maximum of 50w/$m^2$,

e) Surface Temperature, T*

The difference between trial and operational forecasts of T* at 12Z was most noticeable over North Africa with the trial forecasts being 4-12 degrees absolute lower. Over

Europe, differences were small, only 1-2 degrees absolute.

f) Screen Temperature, 1.5m

The impact of the increased vegetative roughness was generally small (+1-2 degrees absolute), even over the desert. Small increases of 1-2 degrees over Southern England were beneficial in the cases rerun.

g) Temperature verification (Section 5b)

Differences were small, with the trial verification showing a reduced bias in the boundary layer but a slightly larger RMS error at level 1.

h) Surface latent heat fluxes

The overall pattern was much the same, but local large differences of +/- 100 w/m$^2$ occurred in areas of heavy showers.

**5. Objective verification of summer cases against ACOBS files**

a) PSTAR

| | Mean Error | | RMS Error | |
|---|---|---|---|---|
| | Trial | Oper | Trial | Oper |
| T+12 | -0.07 | -0.07 | 1.32 | 1.35 |
| T+24 | 0.43 | 0.45 | 1.82 | 1.87 |
| T+36 | 0.43 | 0.43 | 2.58 | 2.63 |

b) TEMPERATURES (radiosonde ascents) ACOBS 201

| Mean Error | T+12 | | T+24 | | T+36 | |
|---|---|---|---|---|---|---|
| | Trial | Oper | Trial | Oper | Trial | Oper |
| level 1 | 0.29 | 0.32 | 1.45 | 1.36 | 1.06 | 1.09 |
| level 2 | 0.32 | 0.34 | 0.60 | 0.53 | 0.77 | 0.79 |
| level 3 | 0.05 | 0.09 | 0.47 | 0.48 | 0.44 | 0.48 |
| level 4 | 0.03 | 0.06 | 0.42 | 0.44 | 0.27 | 0.32 |
| level 5 | 0.09 | 0.10 | 0.32 | 0.32 | 0.40 | 0.41 |
| level 6 | 0.05 | 0.05 | 0.07 | 0.07 | 0.14 | 0.15 |
| level 7 | 0.09 | 0.09 | 0.03 | 0.03 | -0.03 | -0.03 |
| level 8 | 0.03 | 0.03 | 0.01 | 0.01 | 0.04 | 0.04 |
| level 9 | 0.19 | 0.19 | 0.23 | 0.23 | 0.33 | 0.33 |
| level 10 | 0.38 | 0.38 | 0.55 | 0.55 | 0.61 | 0.61 |
| level 11 | 0.57 | 0.56 | 0.81 | 0.81 | 0.86 | 0.85 |
| level 12 | 0.33 | 0.32 | 0.68 | 0.67 | 0.90 | 0.89 |

| | | | | | | |
|---|---|---|---|---|---|---|
| level 13 | 0.20 | 0.20 | 0.31 | 0.31 | 0.48 | 0.47 |
| level 14 | 0.06 | 0.06 | 0.05 | 0.05 | 0.07 | 0.07 |
| level 15 | 0.16 | 0.16 | 0.25 | 0.25 | 0.22 | 0.22 |
| level 16 | 0.31 | 0.31 | 0.62 | 0.62 | 0.66 | 0.66 |
| level 17 | 0.23 | 0.23 | 0.61 | 0.61 | 0.72 | 0.71 |
| level 18 | 0.12 | 0.12 | 1.99 | 1.99 | 1.52 | 1.53 |

| RMS Error | T+12 | | T+24 | | T+36 | |
|---|---|---|---|---|---|---|
| | Trial | Oper | Trial | Oper | Trial | Oper |
| level 1 | 2.43 | 2.37 | 3.08 | 2.99 | 3.23 | 3.23 |
| level 2 | 1.74 | 1.74 | 2.12 | 2.12 | 2.52 | 2.54 |
| level 3 | 1.58 | 1.58 | 1.79 | 1.80 | 2.14 | 2.15 |
| level 4 | 1.28 | 1.28 | 1.55 | 1.57 | 1.96 | 1.98 |
| level 5 | 1.11 | 1.11 | 1.43 | 1.44 | 1.79 | 1.80 |
| level 6 | 1.04 | 1.04 | 1.23 | 1.24 | 1.53 | 1.54 |
| level 7 | 0.99 | 0.99 | 1.16 | 1.17 | 1.49 | 1.49 |
| level 8 | 1.05 | 1.05 | 1.22 | 1.22 | 1.41 | 1.41 |
| level 9 | 1.12 | 1.12 | 1.27 | 1.27 | 1.55 | 1.55 |
| level 10 | 1.27 | 1.27 | 1.42 | 1.42 | 1.76 | 1.76 |
| level 11 | 1.49 | 1.49 | 1.68 | 1.67 | 1.58 | 1.57 |
| level 12 | 1.58 | 1.58 | 1.83 | 1.83 | 2.29 | 2.29 |
| level 13 | 1.40 | 1.40 | 1.87 | 1.88 | 2.14 | 2.15 |
| level 14 | 1.20 | 1.20 | 1.36 | 1.37 | 1.57 | 1.57 |
| level 15 | 0.92 | 0.92 | 0.93 | 0.93 | 0.98 | 0.99 |
| level 16 | 1.03 | 1.03 | 1.12 | 1.12 | 1.16 | 1.16 |
| level 17 | 1.22 | 1.22 | 1.49 | 1.49 | 1.32 | 1.31 |
| level 18 | 1.87 | 1.87 | 2.65 | 2.65 | 2.24 | 2.24 |

c) WINDS (radiosonde ascents) ACOBS 301

| RMS Error | T+12 | | T+24 | | T+36 | |
|---|---|---|---|---|---|---|
| | Trial | Oper | Trial | Oper | Trial | Oper |
| level 1 | 4.20 | 4.25 | 5.00 | 5.11 | 5.09 | 5.23 |
| level 2 | 4.67 | 4.77 | 5.70 | 5.83 | 5.77 | 5.94 |
| level 3 | 4.52 | 4.58 | 5.37 | 5.41 | 6.21 | 6.35 |
| level 4 | 4.17 | 4.19 | 5.02 | 5.05 | 6.00 | 6.06 |
| level 5 | 3.85 | 3.87 | 4.85 | 4.90 | 5.92 | 5.97 |
| level 6 | 3.94 | 3.95 | 4.81 | 4.84 | 5.86 | 5.91 |
| level 7 | 4.08 | 4.09 | 4.92 | 4.94 | 6.08 | 6.12 |

| | | | | | | |
|---|---|---|---|---|---|---|
| level 8 | 4.58 | 4.56 | 5.39 | 5.41 | 6.75 | 6.78 |
| level 9 | 5.01 | 5.03 | 5.97 | 5.99 | 8.01 | 8.05 |
| level 10 | 5.82 | 5.84 | 7.29 | 7.32 | 9.14 | 9.18 |
| level 11 | 6.61 | 6.63 | 8.35 | 8.39 | 9.85 | 9.85 |
| level 12 | 6.34 | 6.35 | 8.20 | 8.21 | 9.60 | 9.60 |
| level 13 | 5.12 | 5.13 | 6.34 | 6.37 | 7.79 | 7.79 |
| level 14 | 4.34 | 4.36 | 4.65 | 4.67 | 5.32 | 5.34 |
| level 15 | 3.15 | 3.15 | 3.43 | 3.45 | 3.77 | 3.78 |
| level 16 | 2.87 | 2.87 | 2.87 | 2.87 | 3.12 | 3.13 |
| level 17 | 2.83 | 2.83 | 2.80 | 2.80 | 2.73 | 2.73 |
| level 18 | 4.09 | 4.09 | 3.58 | 3.58 | 3.32 | 3.32 |

## 6. Conclusions

1. Reduction in 10m windspeed forecasts over land verifies better against observed wind speeds . Clear and consistent improvement in rms wind errors.

2. Very slight increased filling of old depressions over land. (1-2mb at T+36), and better verification , reducing the negative pressure error.

3. General improvement in height and wind verification. Smaller changes in verification scores for temperature and relative humidity but generally improved.

4. Increase in predicted surface sensible heat fluxes and corresponding decrease in predicted surface temperatures (tstar) overland during daytime. Impact small over Europe and America, (max 50-60w/$m^2$, -2 degrees ) but more significant over the desert (max 100-120w/$m^2$, -12 degrees ).

5. Impact on predicted 1.5m temperatures over land small everywhere (plus 0-2 degree).Small increases over the U.K. were beneficial.

The overall assessment is in favour of the increased roughness version. The change to the vegetative roughness lengths may be viewed as an interim measure to correct for the unrealistically low values currently used and until the orographic roughness formulation is developed sufficiently for consideration for operational use.

**References**

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Derivation of Land surface parameter datasets for use in the Met. O. 20 GCM. *Met. O . 20 Internal Note no. 81* .

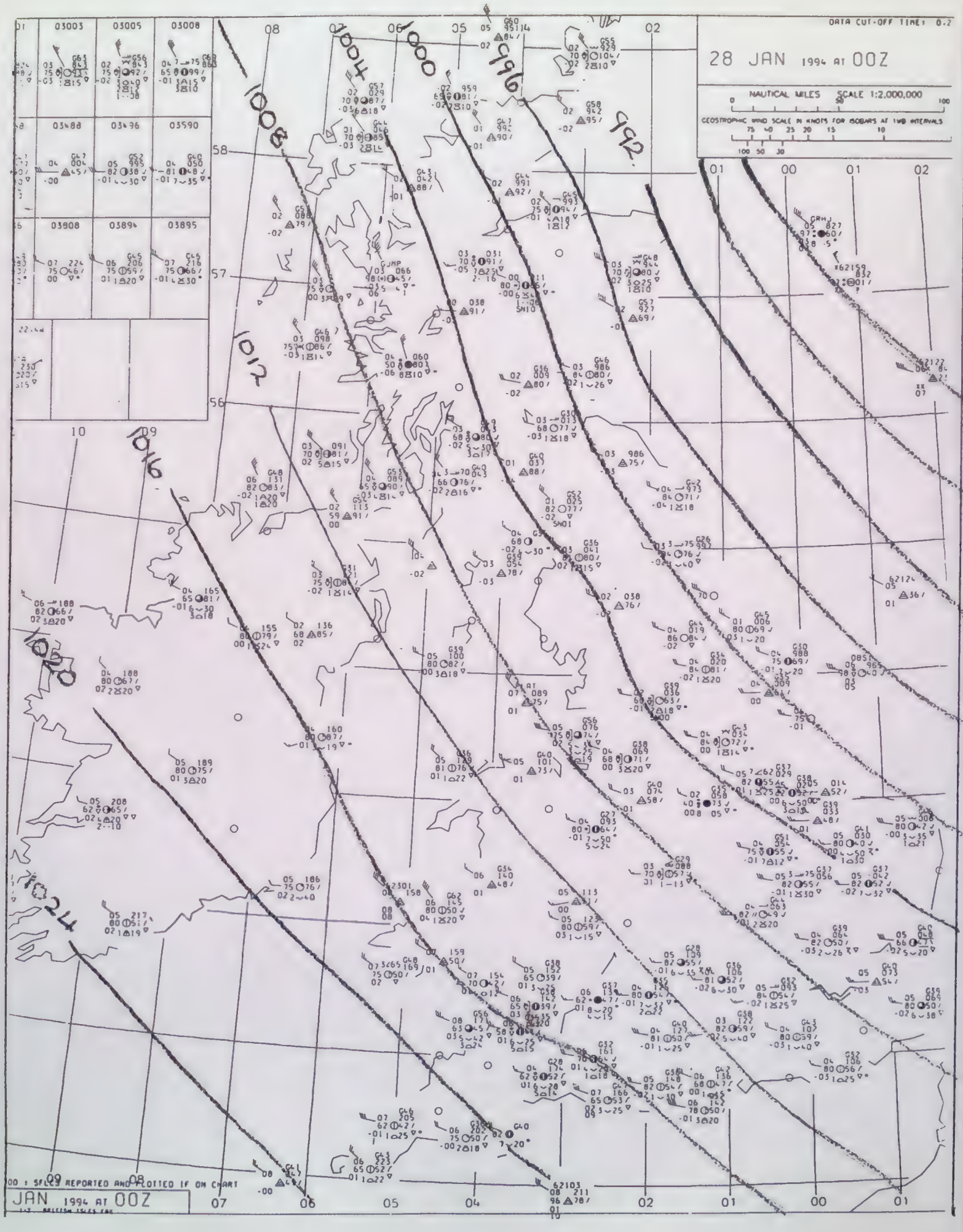
Smith F B and D J Carson, 1977

Some thoughts on the specification of the boundary layer relevant to numerical modelling. *Boundary Layer Met. 12, 307-330.*

Jones C P

Specification of ancillary fields. *Unified Model Documentation Paper No 70.*

**Figure 3.1**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GEOSTROPHIC WIND SCALE IN KNOTS FOR ISOBARS AT 1MB INTERVALS
1004
1000
996
992
988
1008
1012
1016
1020
1024
JAN 1994 AT 00Z

# Figure 3.2

MEAN SEA LEVEL PRESSURE
VALID AT 00Z 28/1/94, DATA TIME 00Z 26/1/94
MSLP FROM OPERATIONAL SUITE
T+48

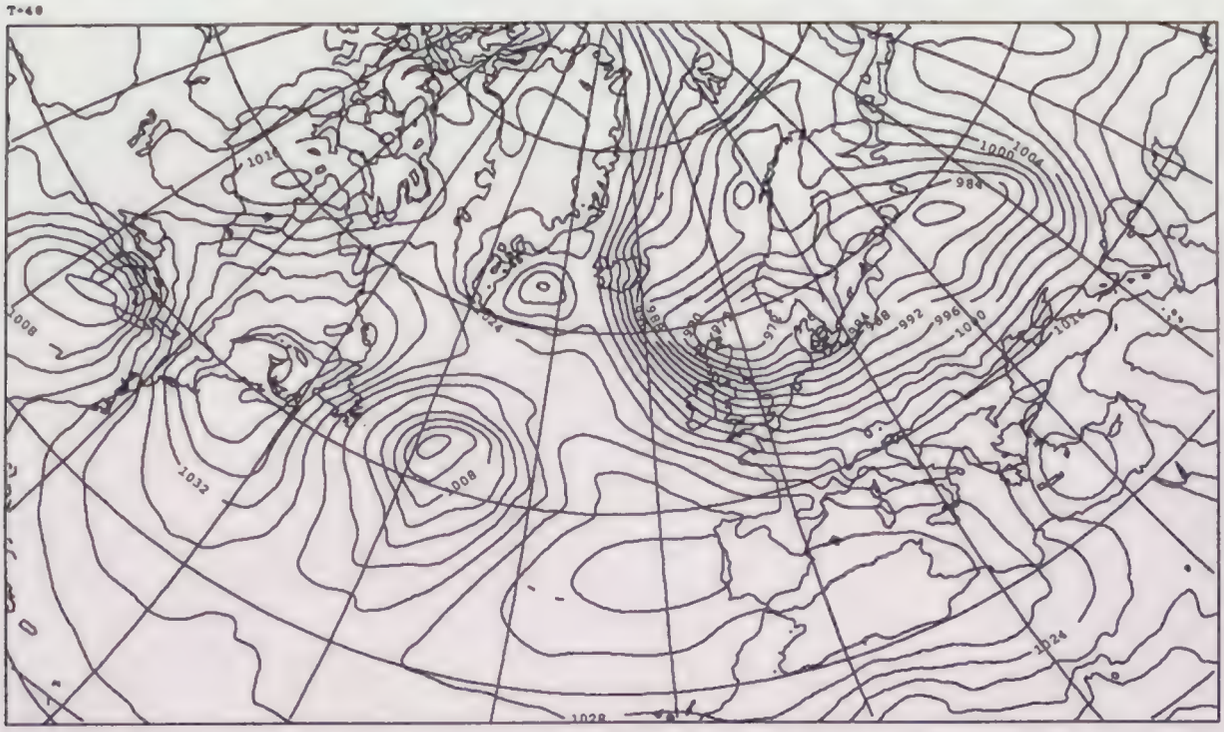



Figure 3.2a

MEAN SEA LEVEL PRESSURE
VALID AT 00Z 28/1/94, DATA TIME 00Z 26/1/94
MSLP FROM PARALLEL SUITE TRIAL OF INCREASED VEGETATION ROUGHNESS
T+48

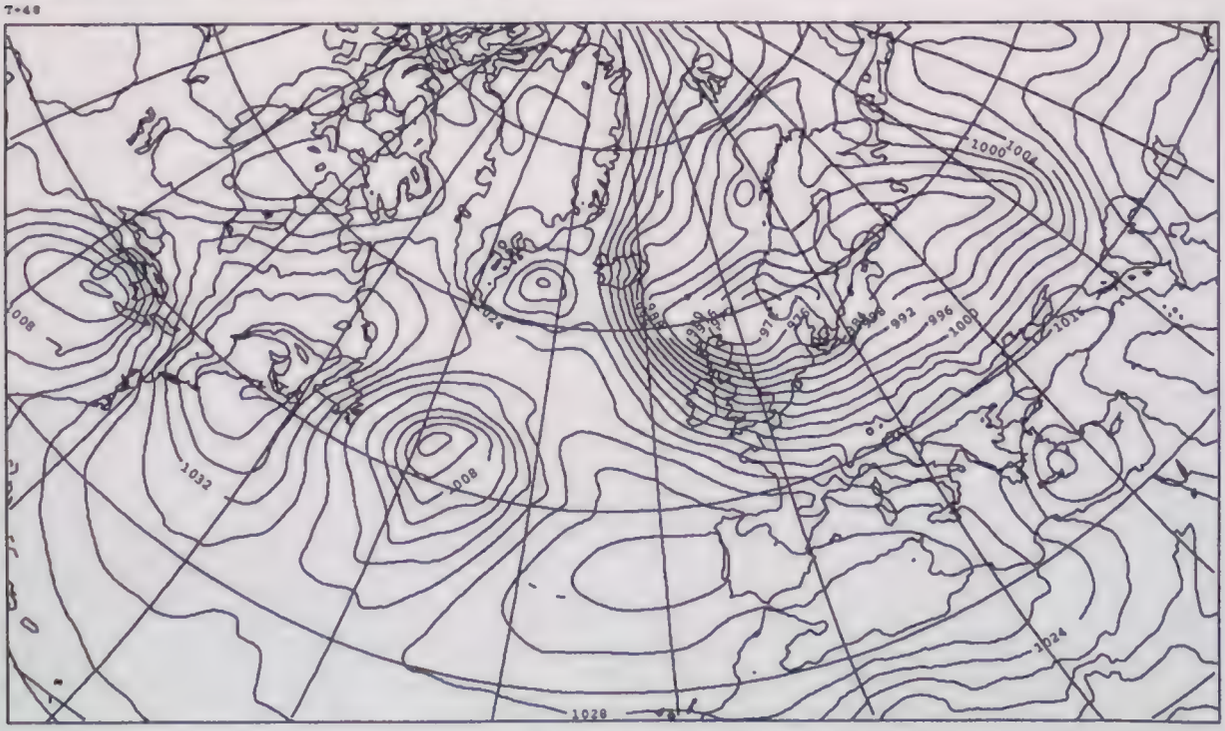



Figure 3.2b

# Figure 3.3

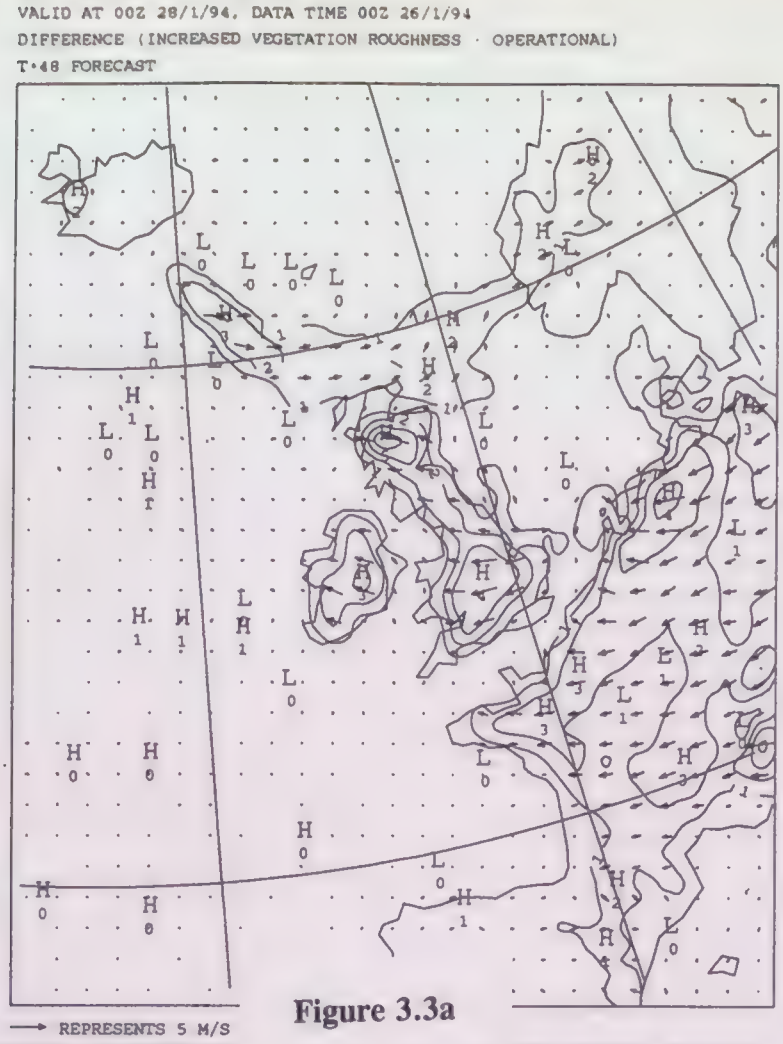



Figure 3.3a

Figure 3.3b

Figure 3.4

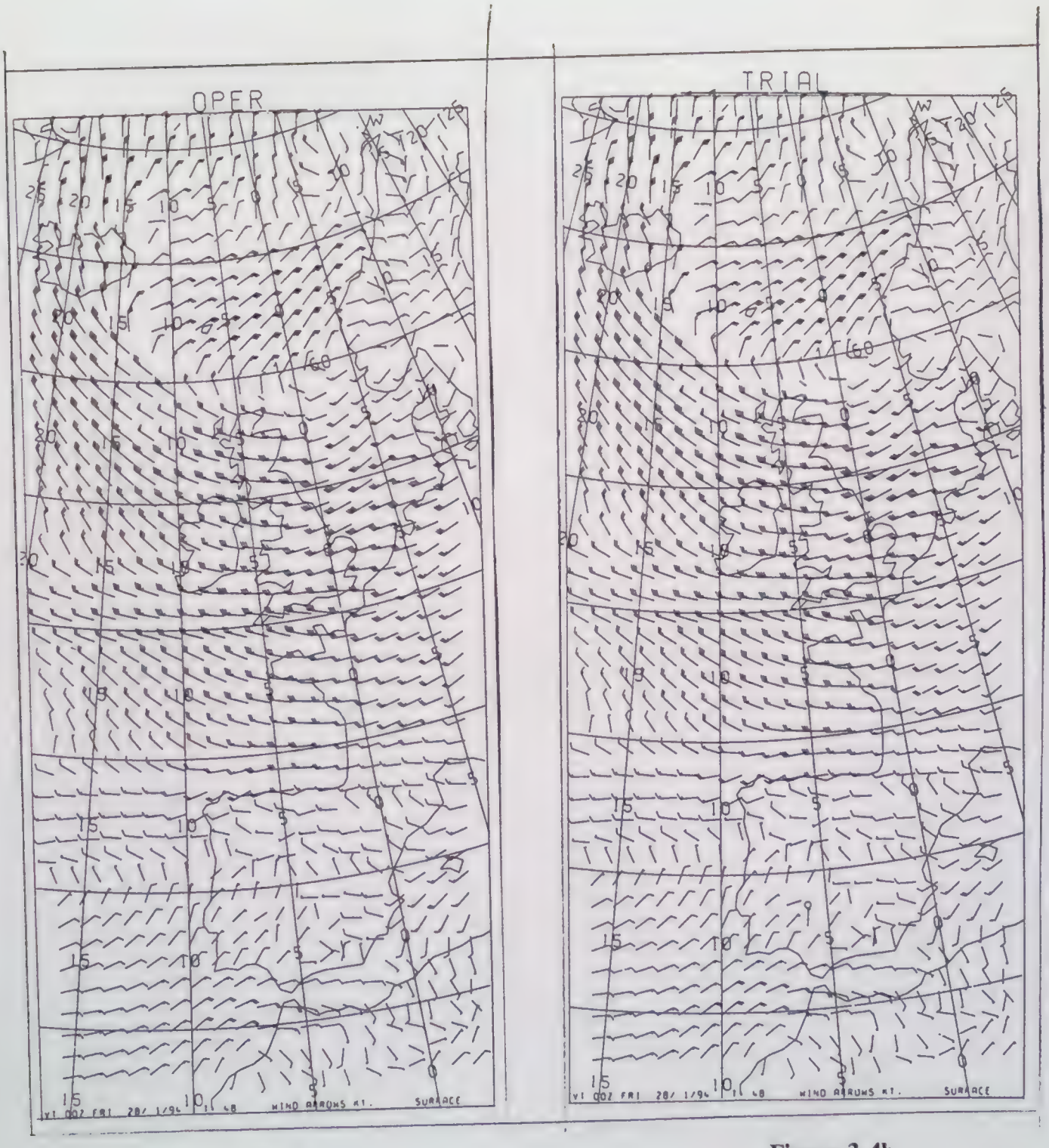
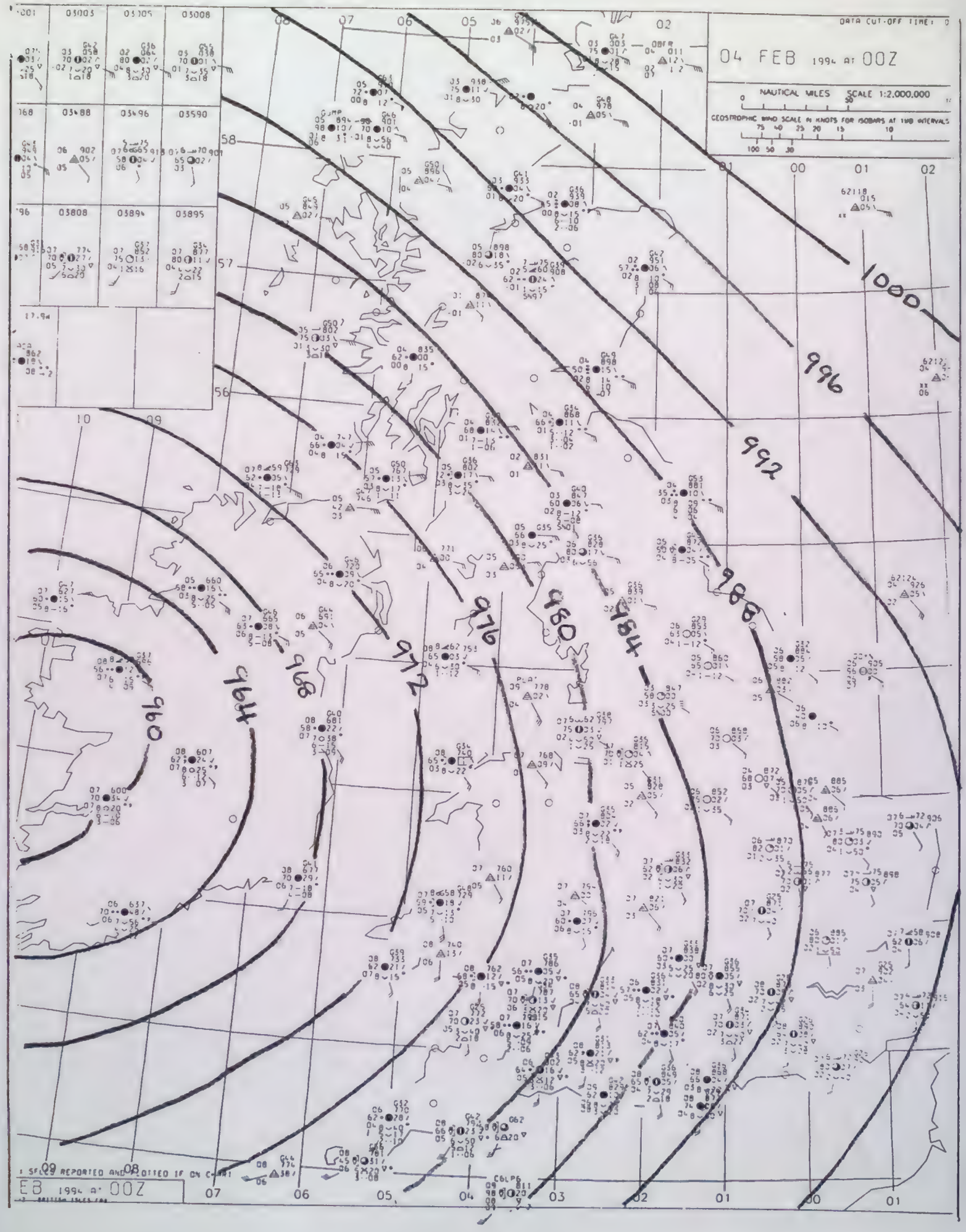



Figure 3.4a

Figure 3.4b

**Figure 3.5**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04 FEB 1994 AT 00Z
NAUTICAL MILES SCALE 1:2,000,000
GEOSTROPHIC WIND SCALE IN KNOTS FOR ISOBARS AT 1MB INTERVALS
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992
988
984
980
976
972
968
964
960
EB 1994 AT 00Z

# Figure 3.6

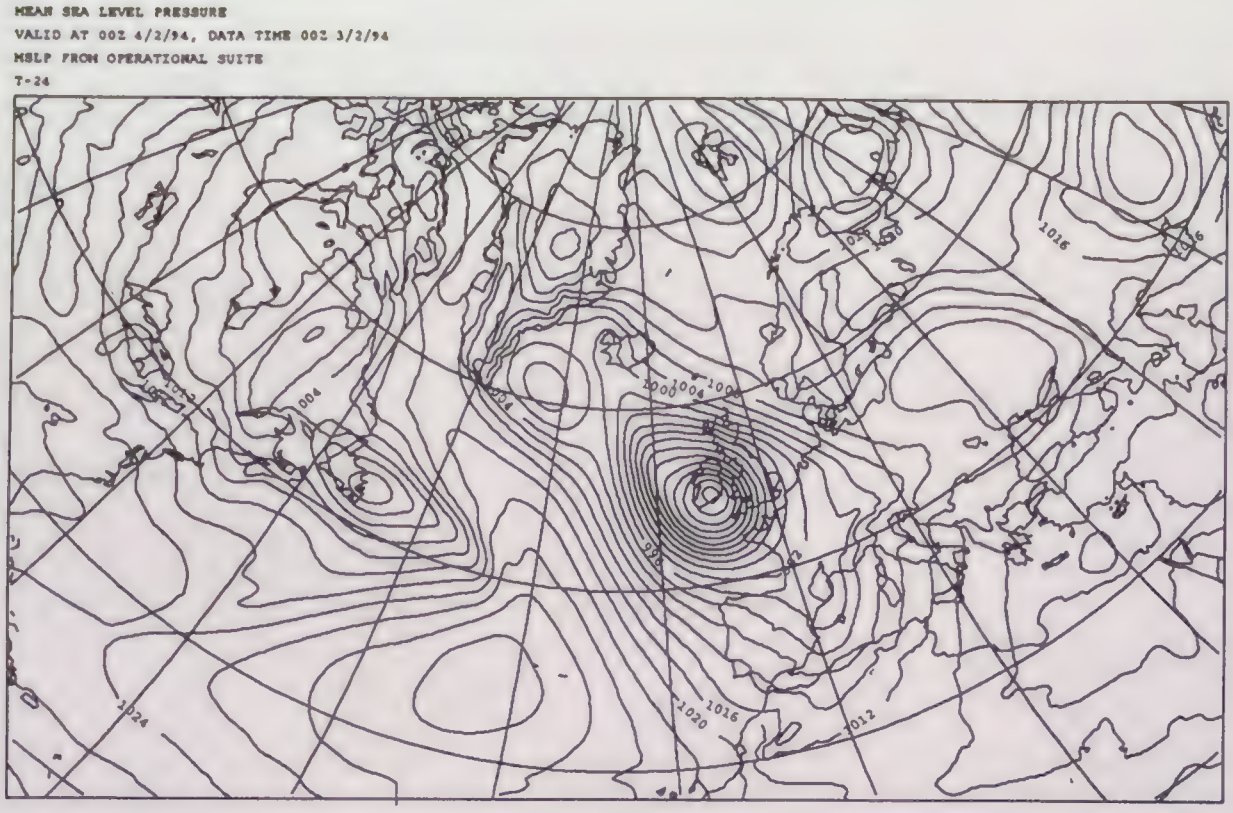



Figure 3.6a

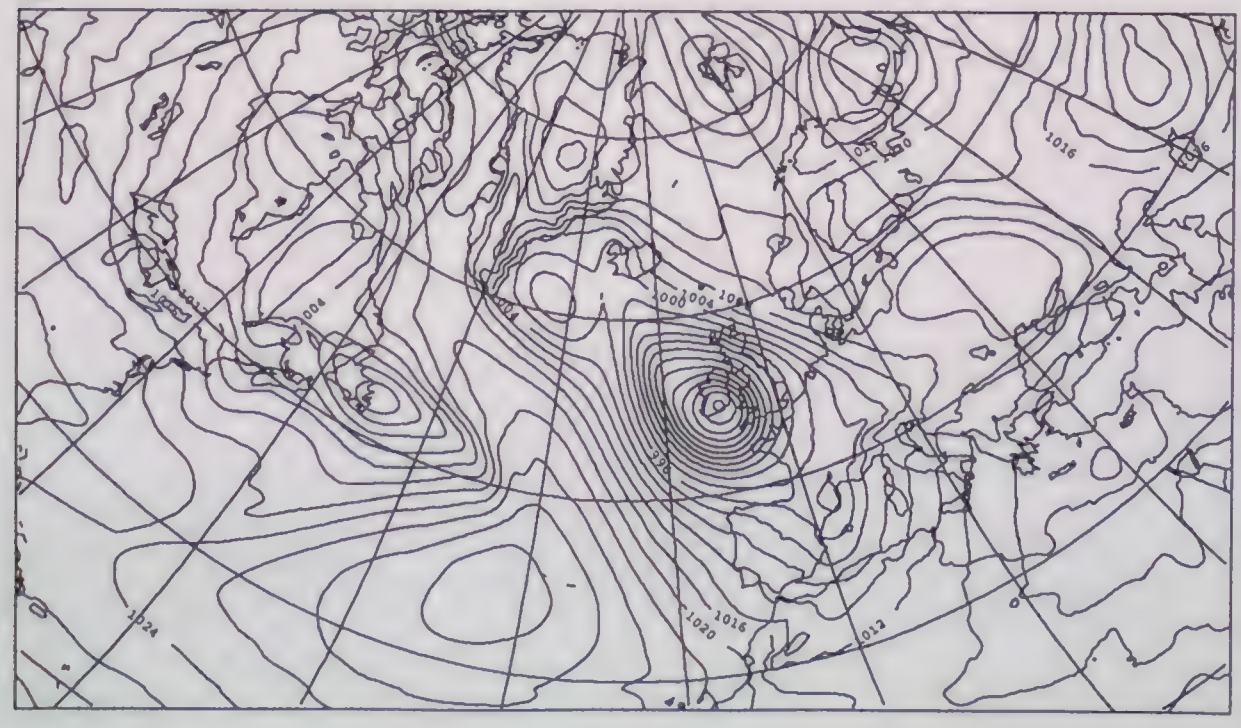



Figure 3.6b

Figure 3.7

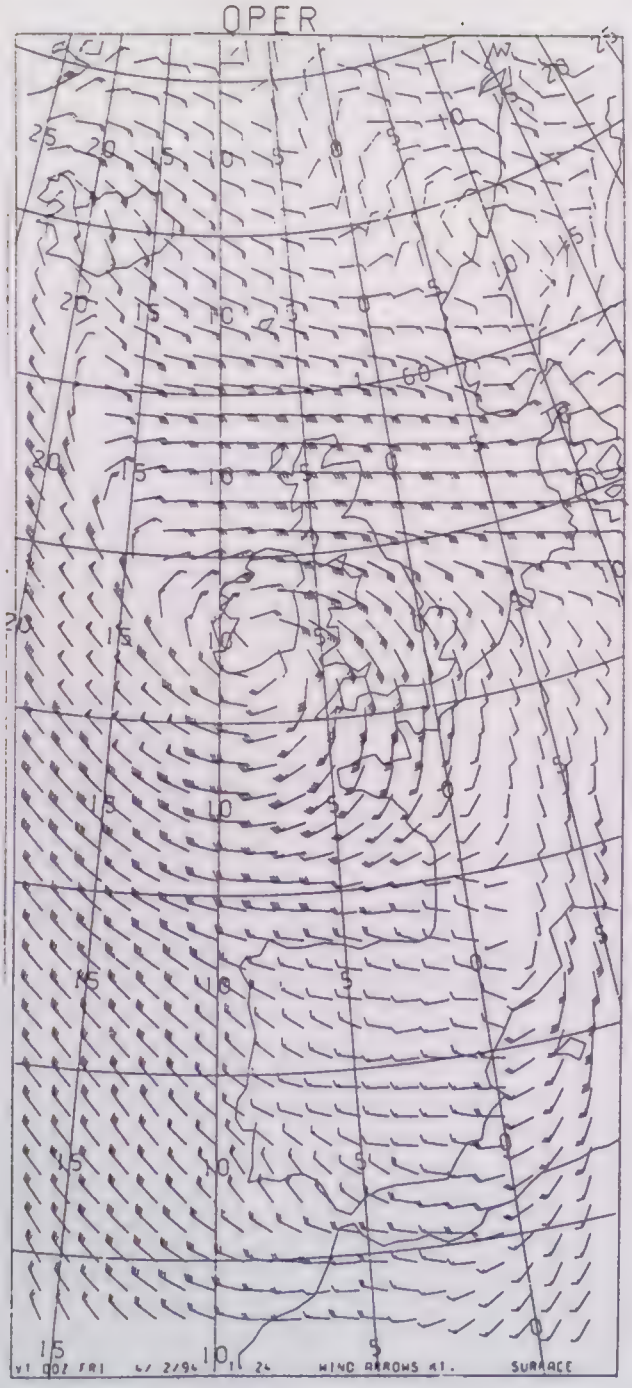



Figure 3.7a

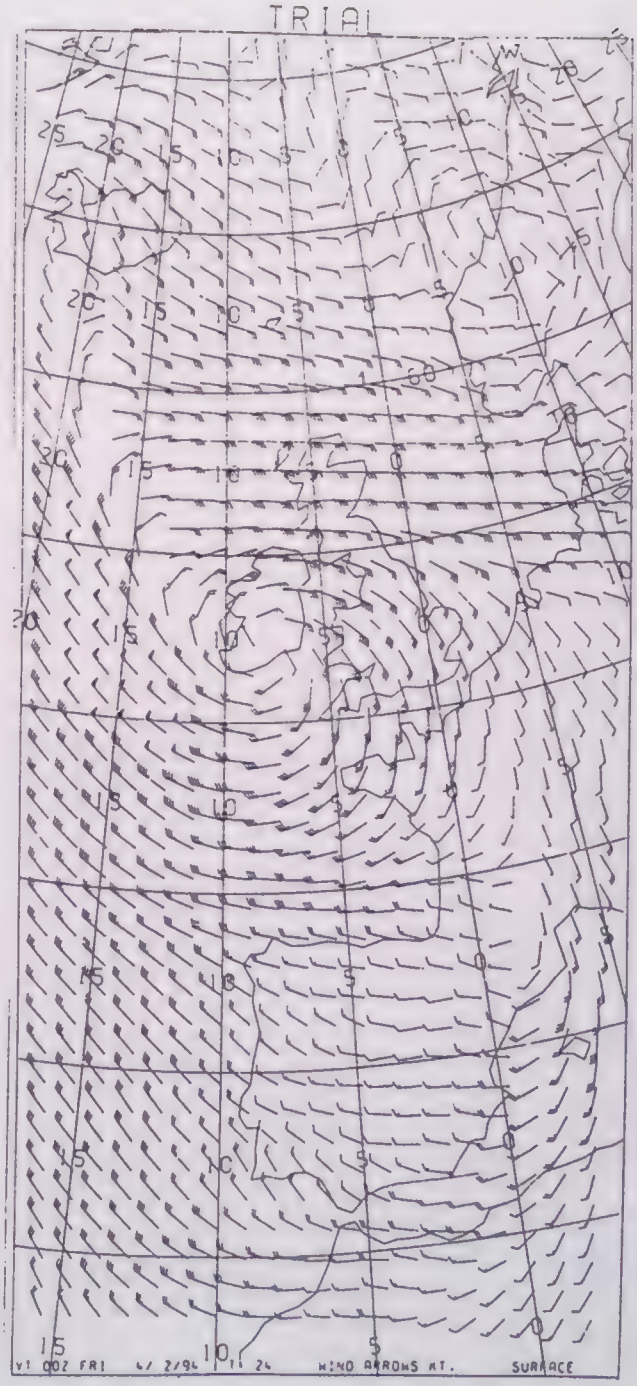
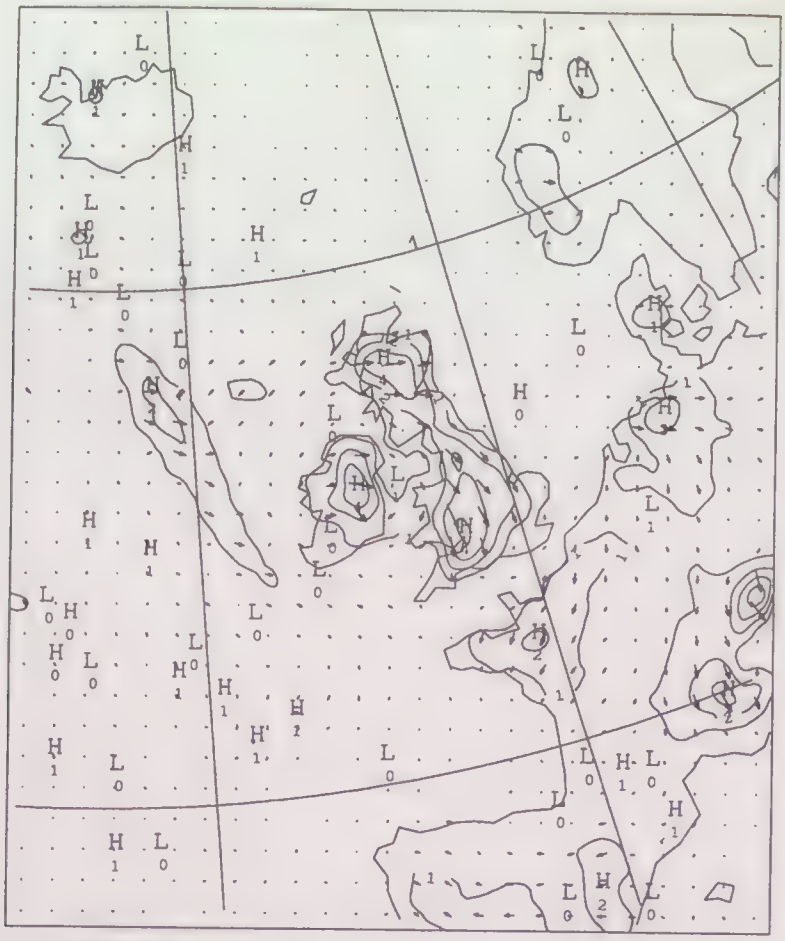



Figure 3.7b

## Figure 3.8

10M WIND DIFFERENCE IN M/S
VALID AT 00Z 4/2/94, DATA TIME 00Z 3/2/94
DIFFERENCE (INCREASED VEGETATION ROUGHNESS - OPERATIONAL)
T+24 FORECAST



REPRESENTS 5 M/S

## Figure 3.8a

MEAN SEA LEVEL PRESSURE DIFFERENCES FROM PARALLEL SUITE TRIAL
VALID AT 00Z 4/2/94, DATA TIME 00Z 3/2/94
MSLP DIFFERENCE (INCREASED VEGETATION ROUGHNESS - OPERATIONAL)
T+24 FORECAST

## Figure 3.8b

**Figure 3.9**

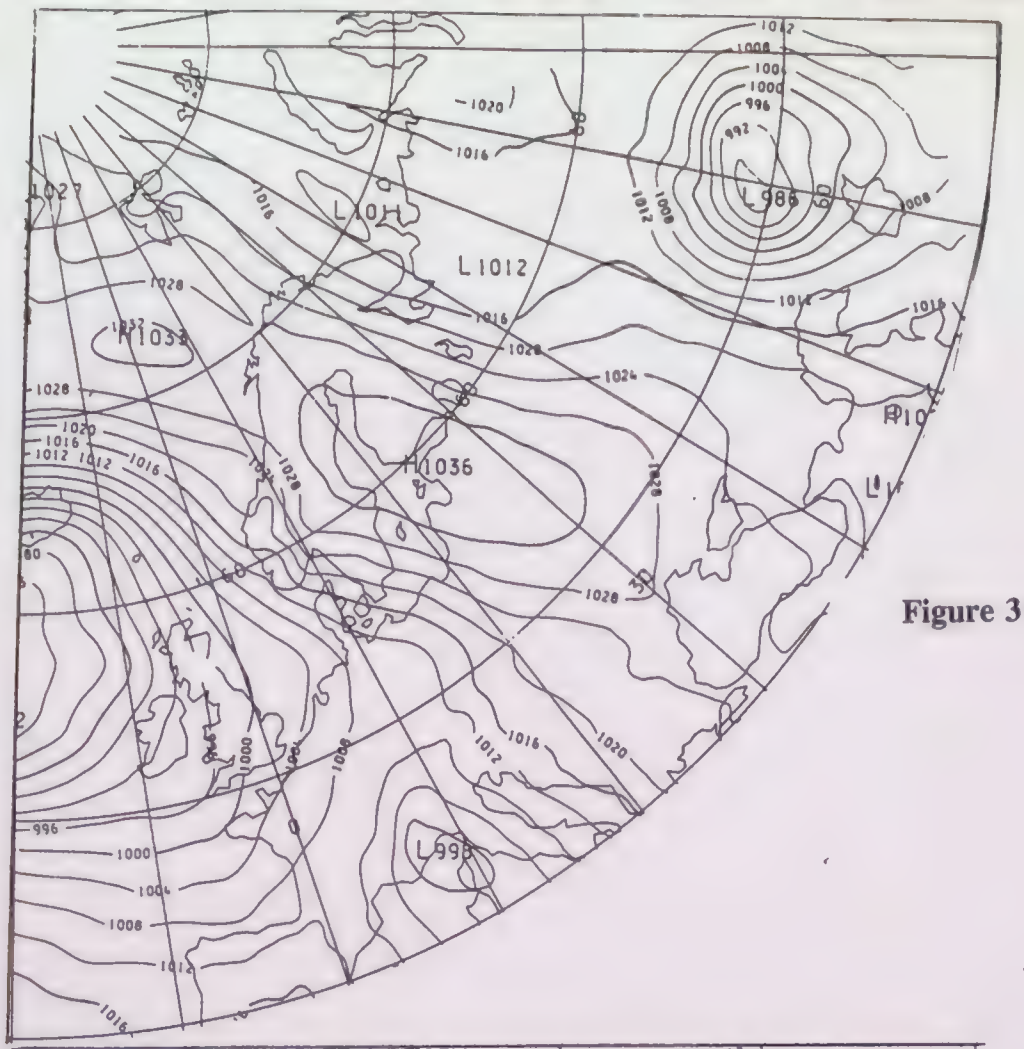



**Figure 3.9a**

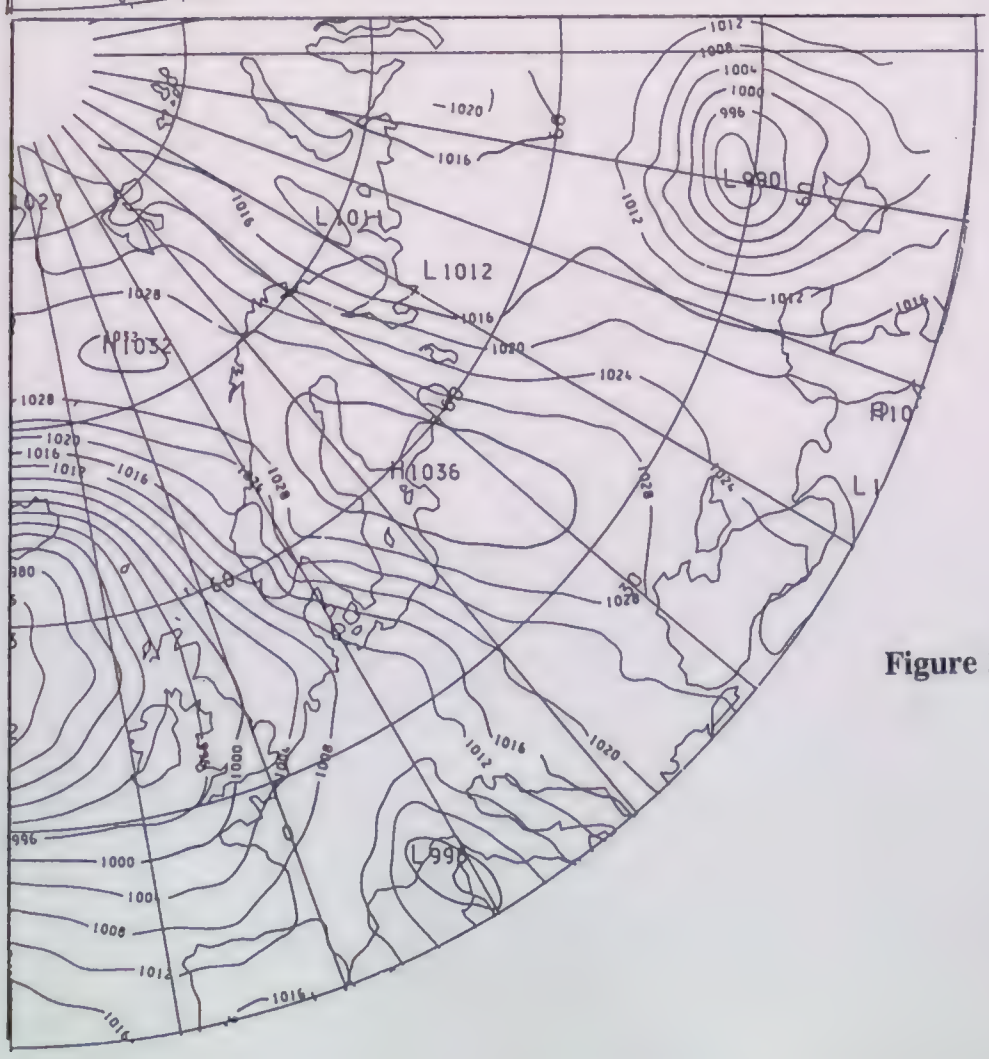



**Figure 3.9b**

**Figure 3.10**

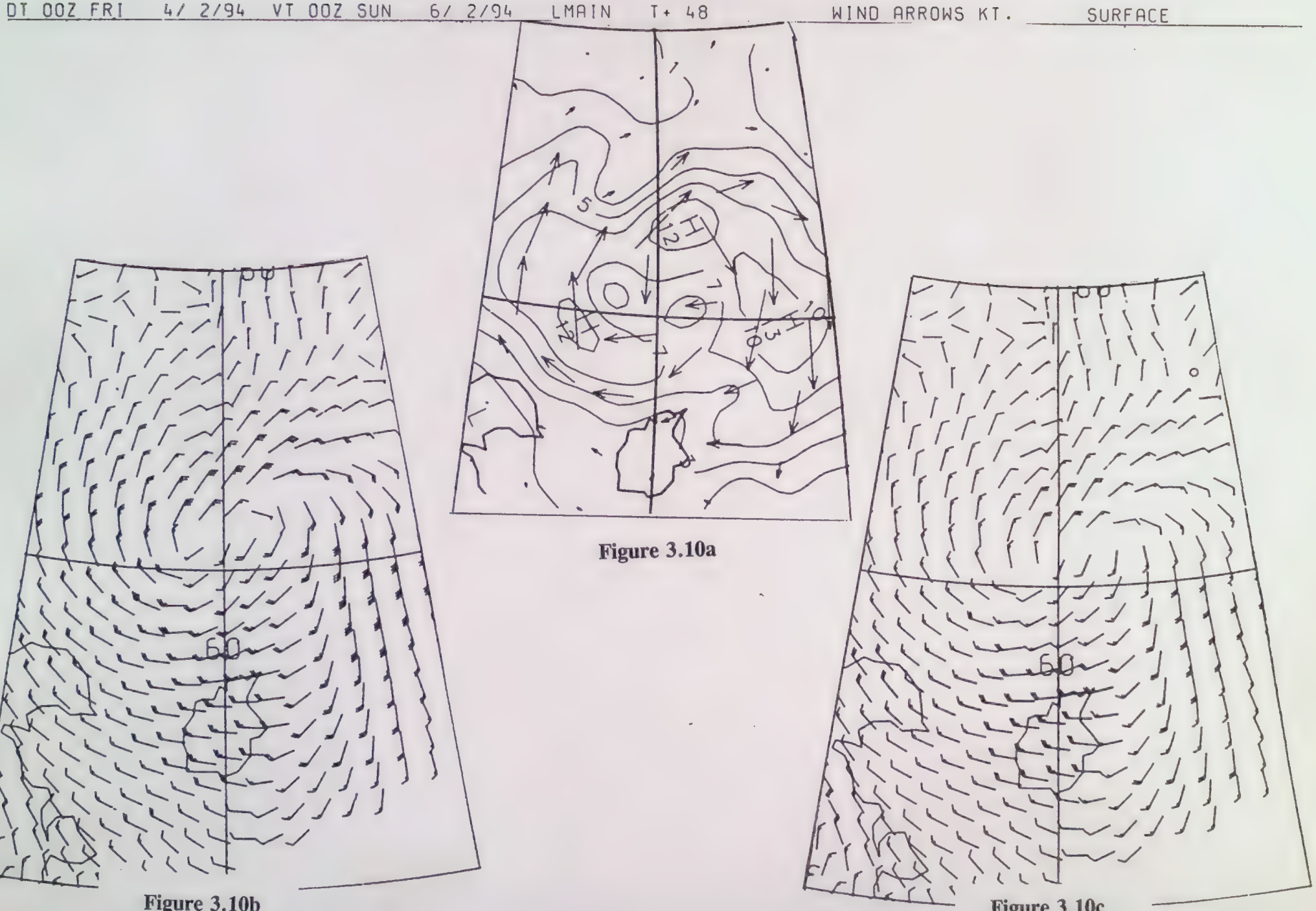



**Figure 3.10a**

**Figure 3.10b**

**Figure 3.10c**

Figure 3.11

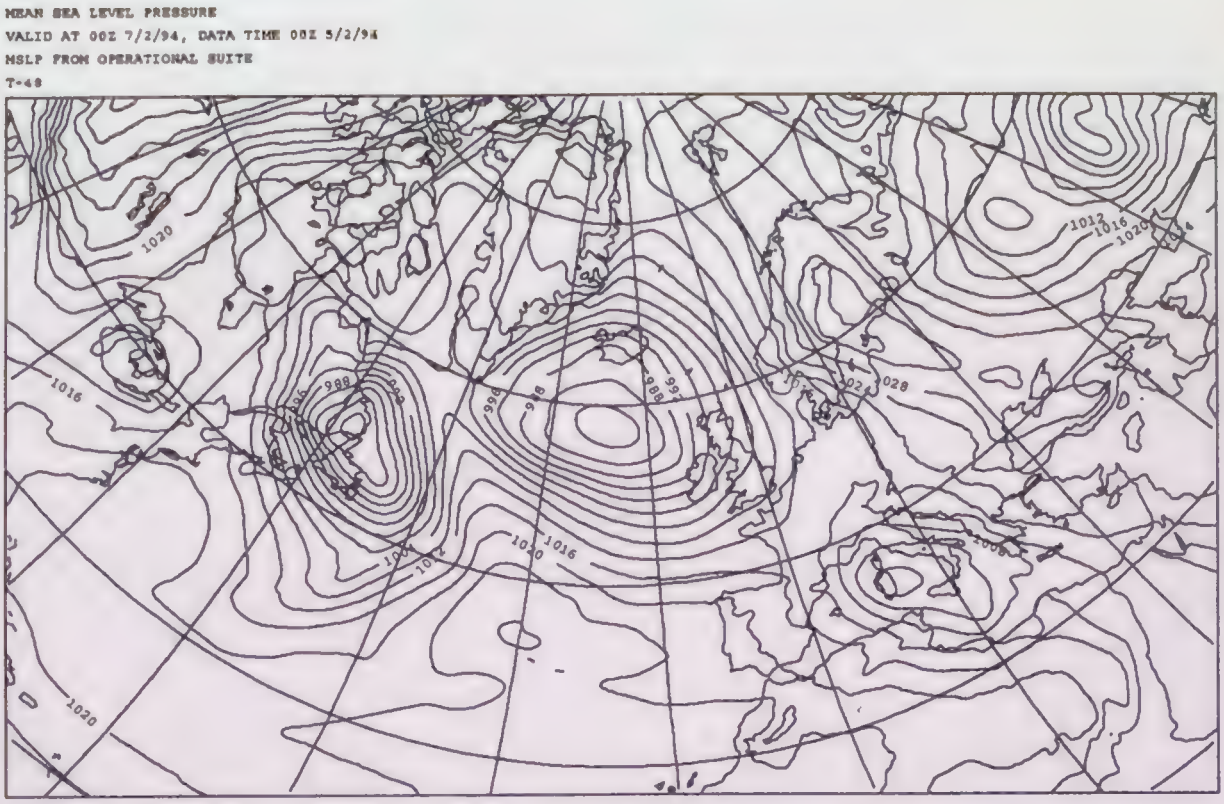



Figure 3.11a

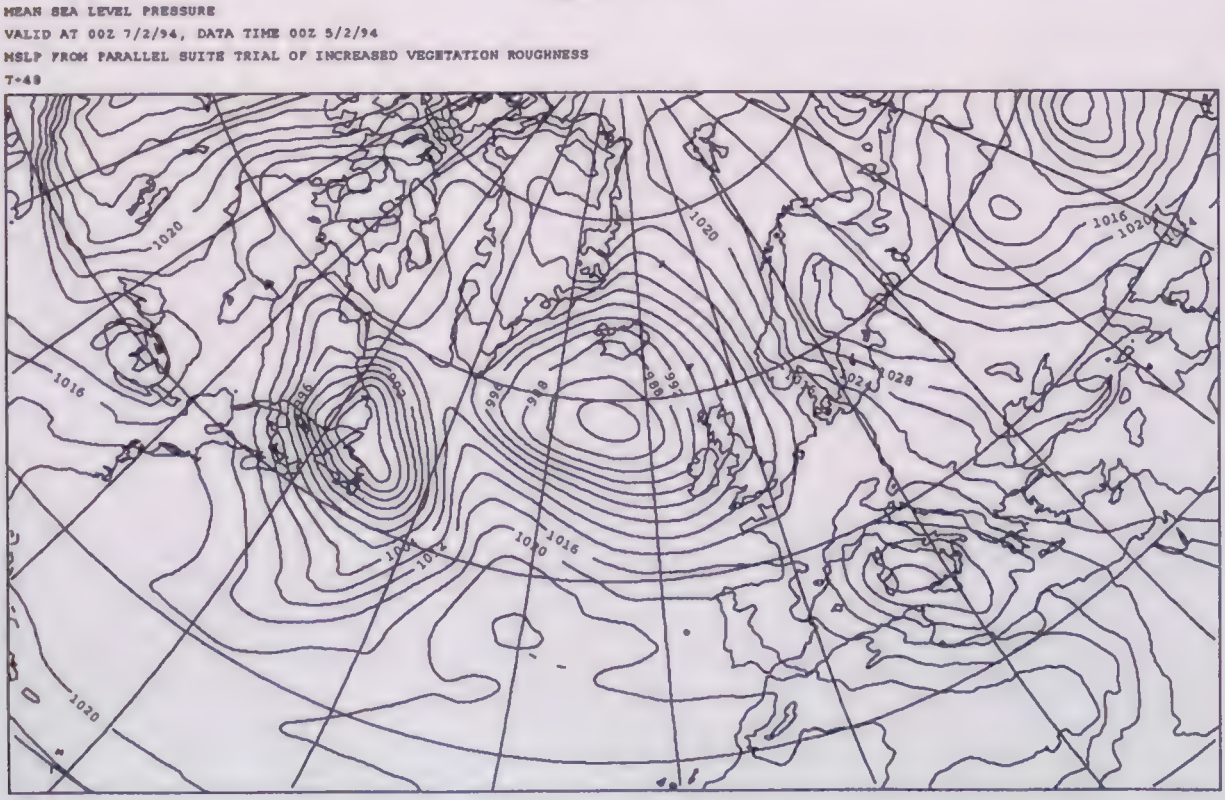



Figure 3.11b

# Figure 3.12

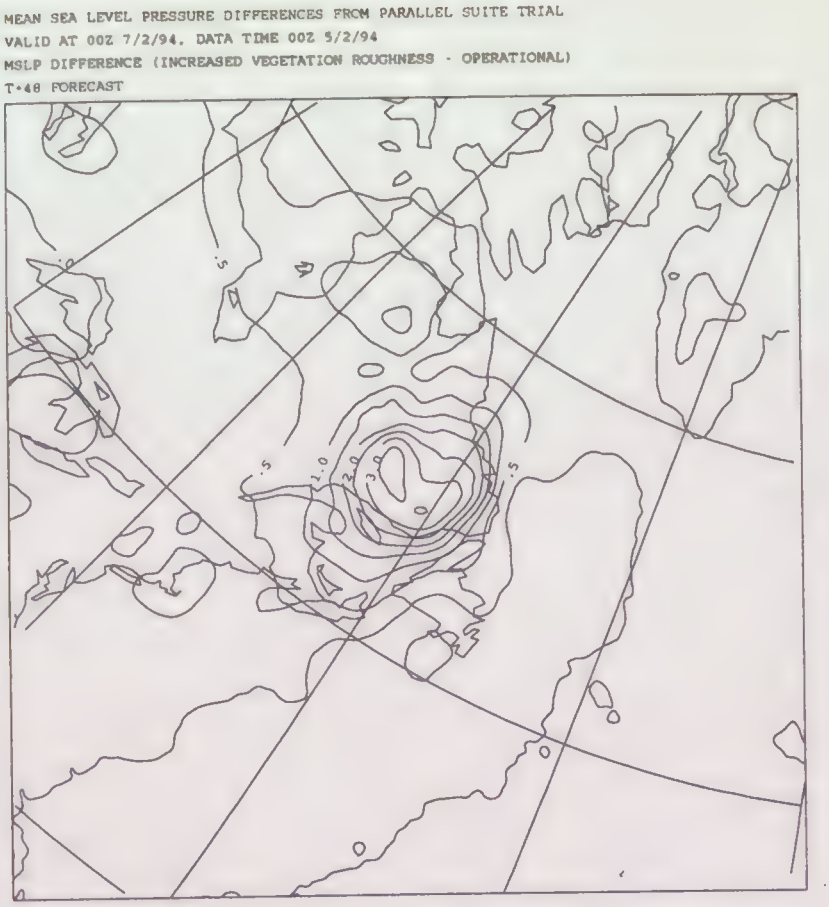



**Figure 3.12a**

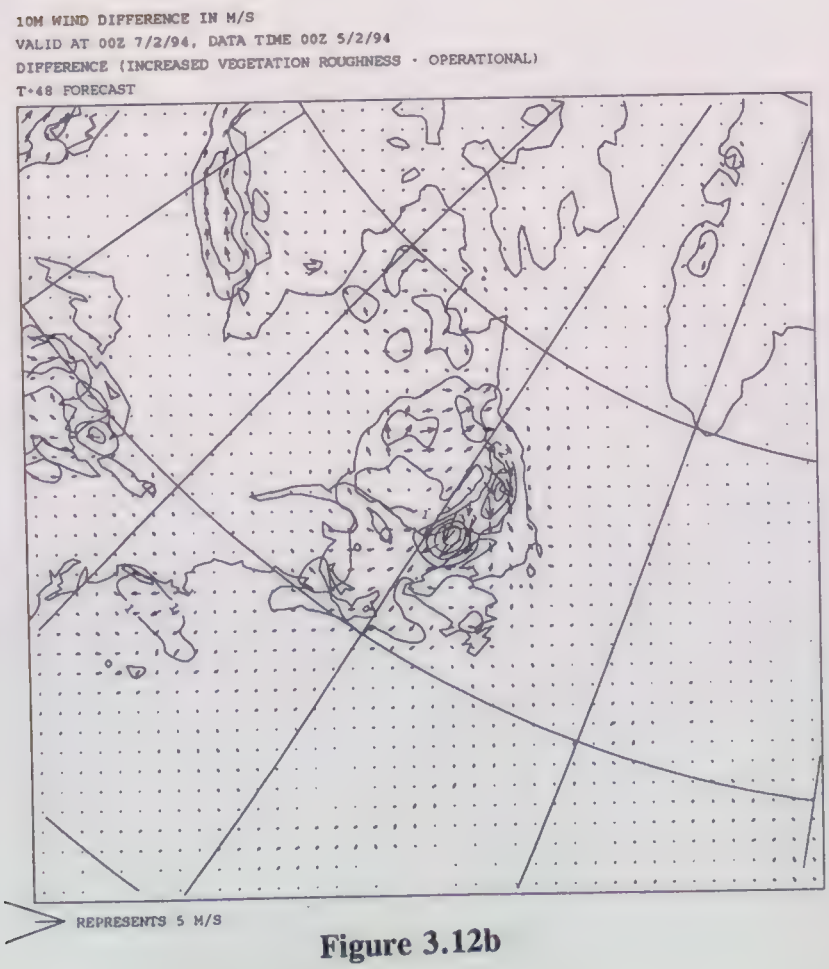



**Figure 3.12b**

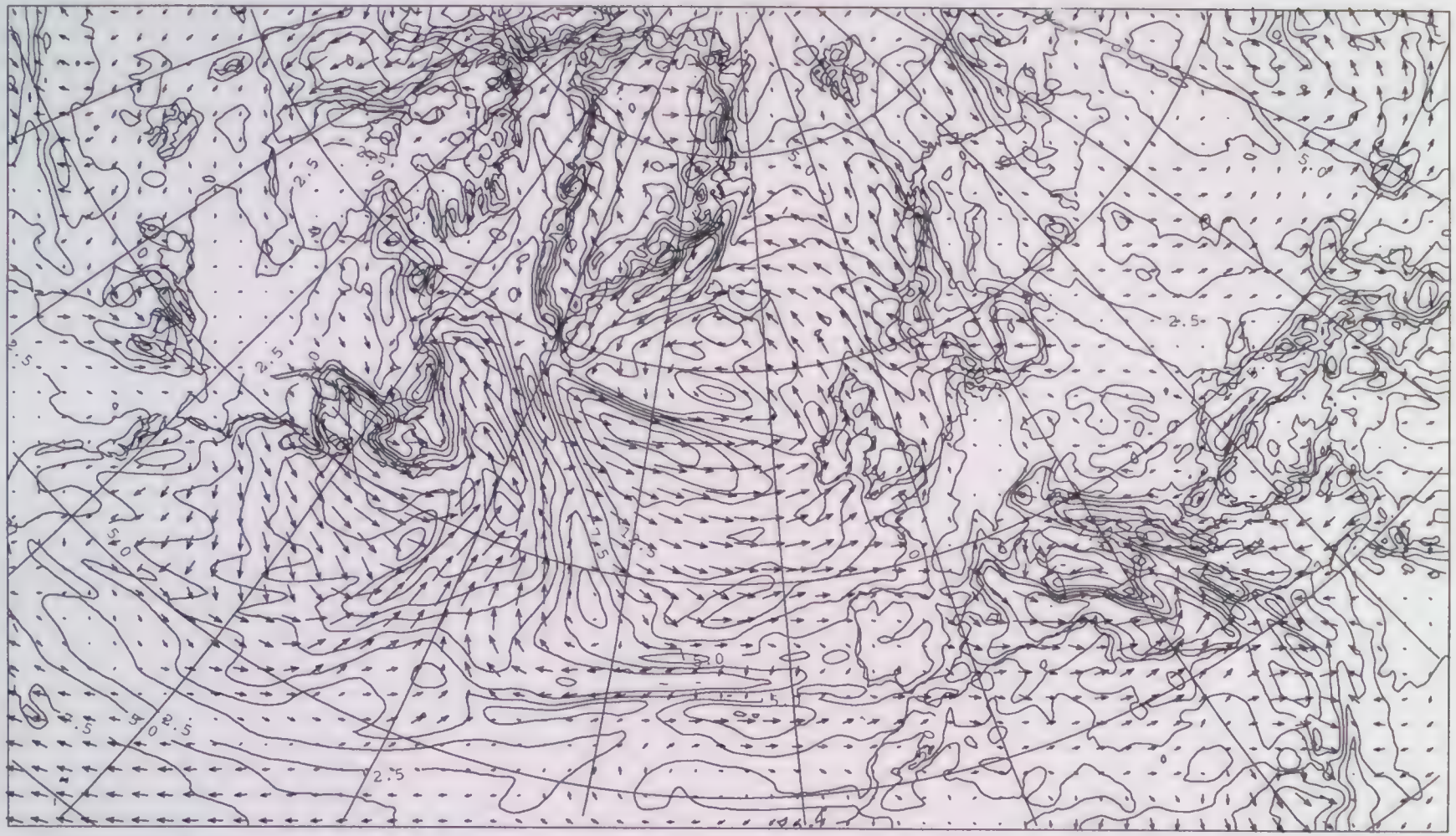
**Figure 3.13**

WIND ARROWS AND ISOTACHS AT 10M

10M WIND FORECAST VALID 00Z 7/2/94 DATA TIME 00Z 5/2/94

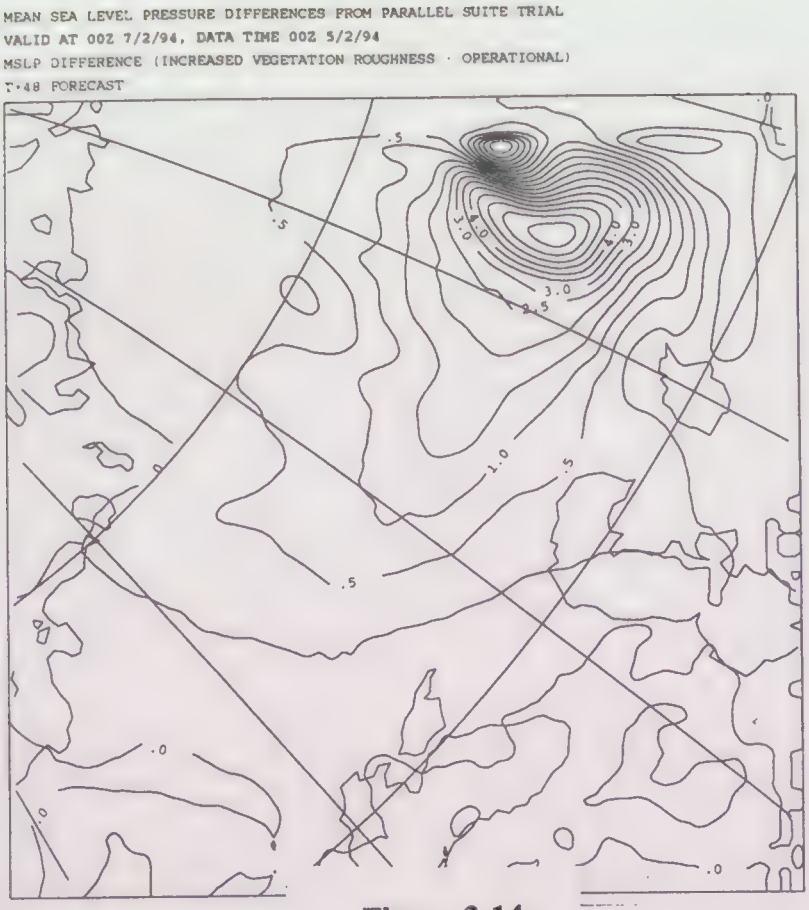
PARALLEL SUITE TRIAL - INCREASED VEGETATION ROUGHNESS

T+48 FORECAST

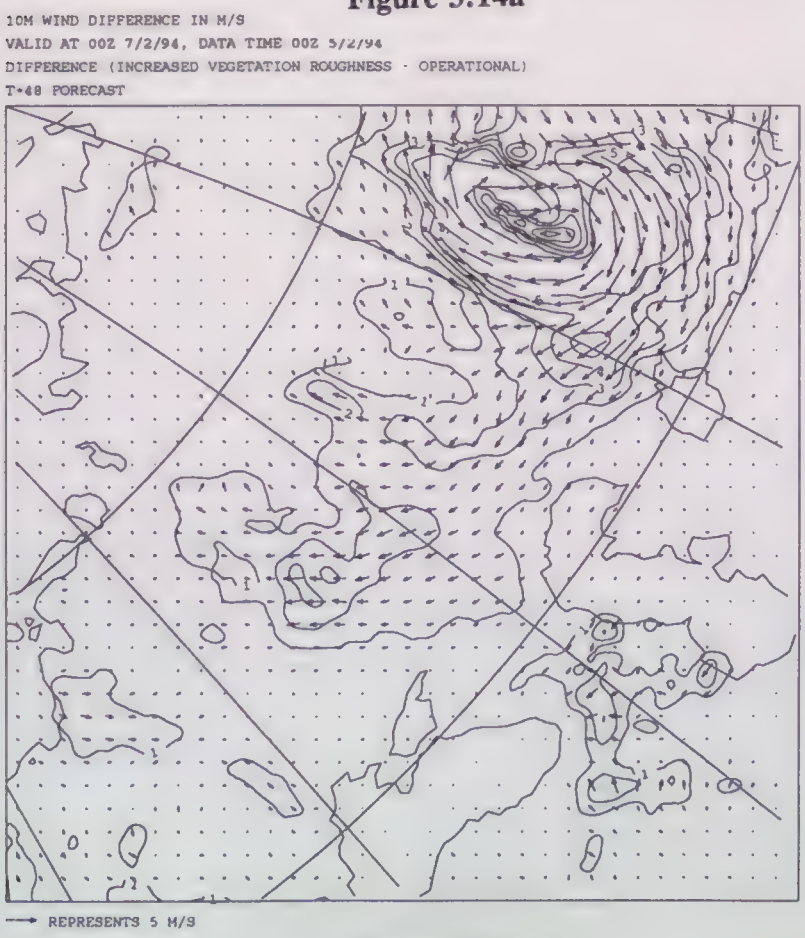


⟶ REPRESENTS 20 M/S

# Figure 3.14



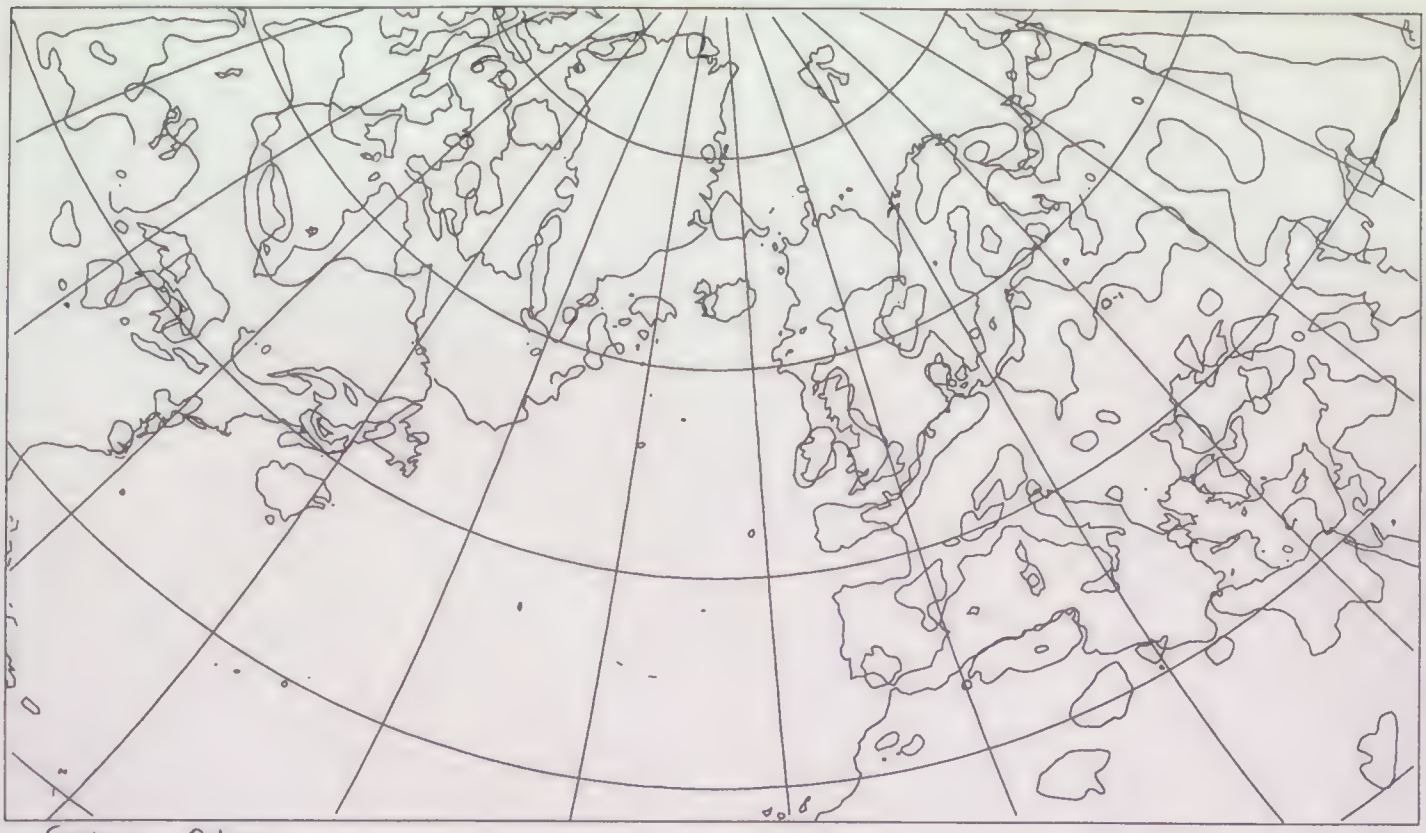

# Figure 3.14a




# Figure 3.14b

## Figure 3.15

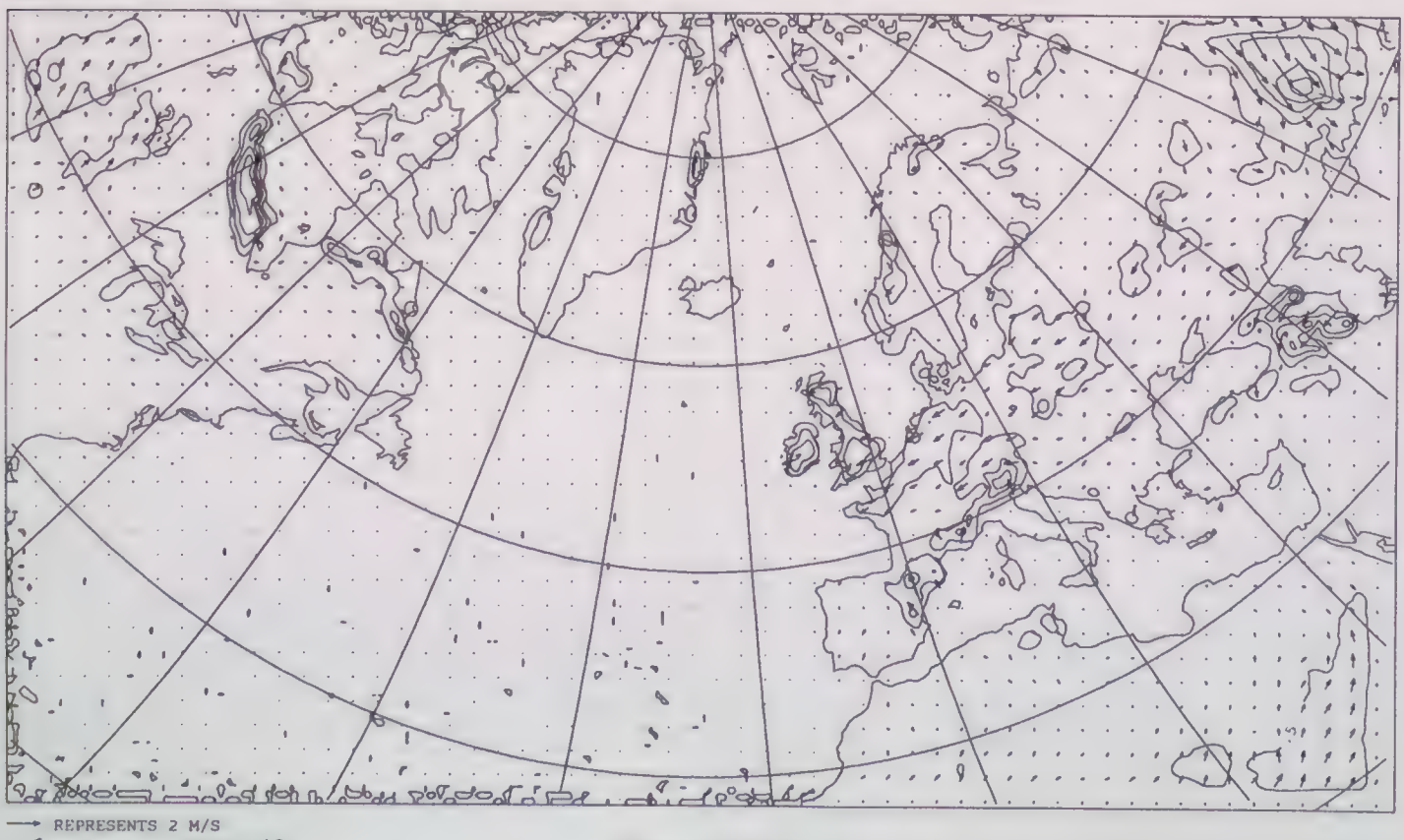
MEAN SEA LEVEL PRESSURE DIFFERENCES
MEAN DIFFERENCE FROM 00Z 22/1/94 TO 00Z 10/2/94
TRIAL (INCREASED VEGETATION ROUGHNESS OPERATIONAL)
T+00



Contour 0·1 mb

## Figure 3.15a

10M WIND DIFFERENCES
MEAN DIFFERENCE FROM 00Z 20/1/94 TO 00Z 8/2/94
TRIAL (INCREASED VEGETATION ROUGHNESS - OPERATIONAL)
T+00



→ REPRESENTS 2 M/S
Contours 0·5 m/s.

## Figure 3.15b

**Figure 3.16**

MEAN SEA LEVEL PRESSURE
AVERAGE FROM 00Z 20/1/94 TO 00Z 8/2/94
PARALLEL SUITE TRIAL - OPERATIONAL
ANALYSIS

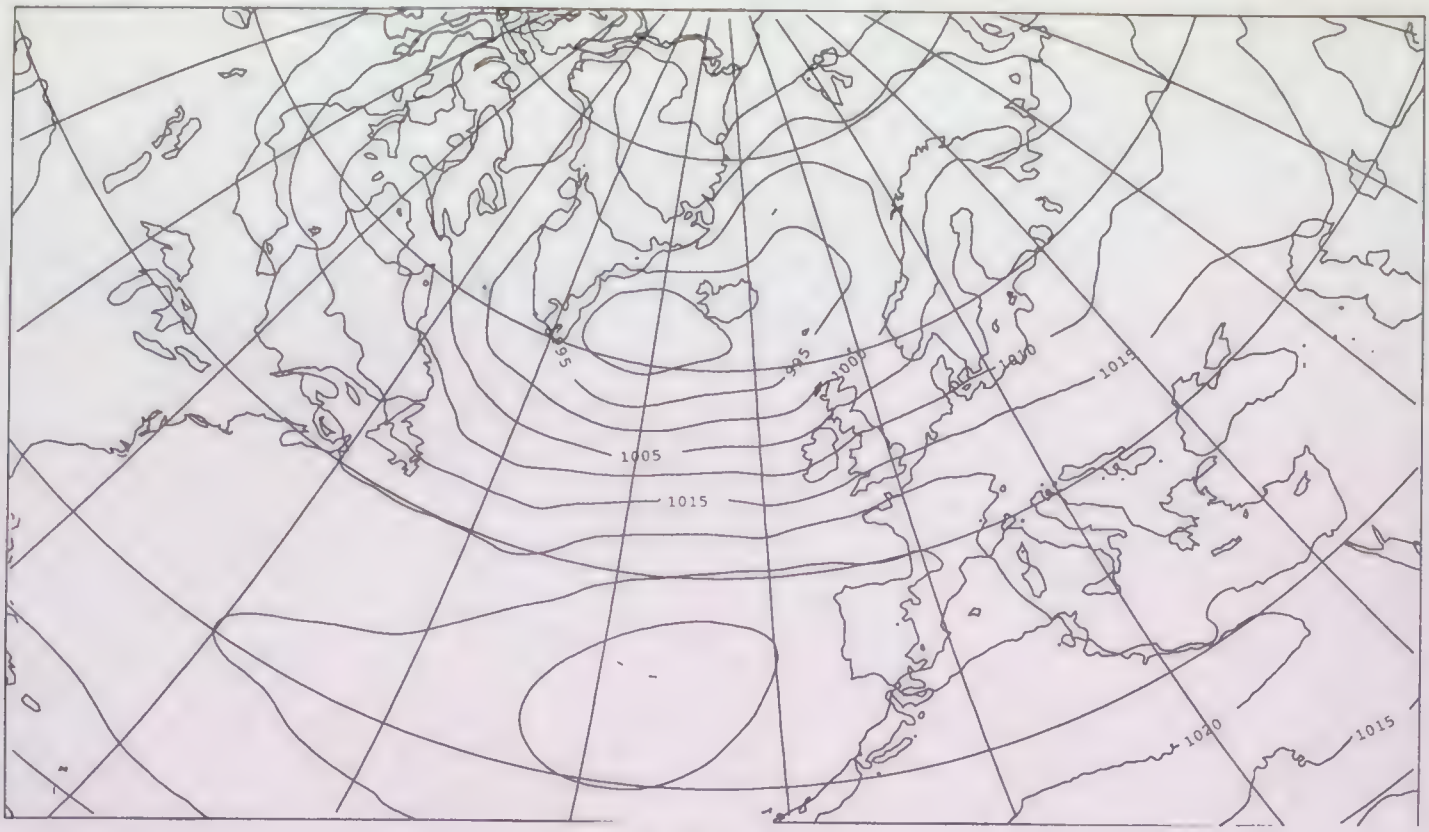



**Figure 3.16a**

MEAN SEA LEVEL PRESSURE
AVERAGE FROM 00Z 26/1/94 TO 00Z 8/2/94
PARALLEL SUITE TRIAL - INCREASED VEGETATION ROUGHNESS
ANALYSIS

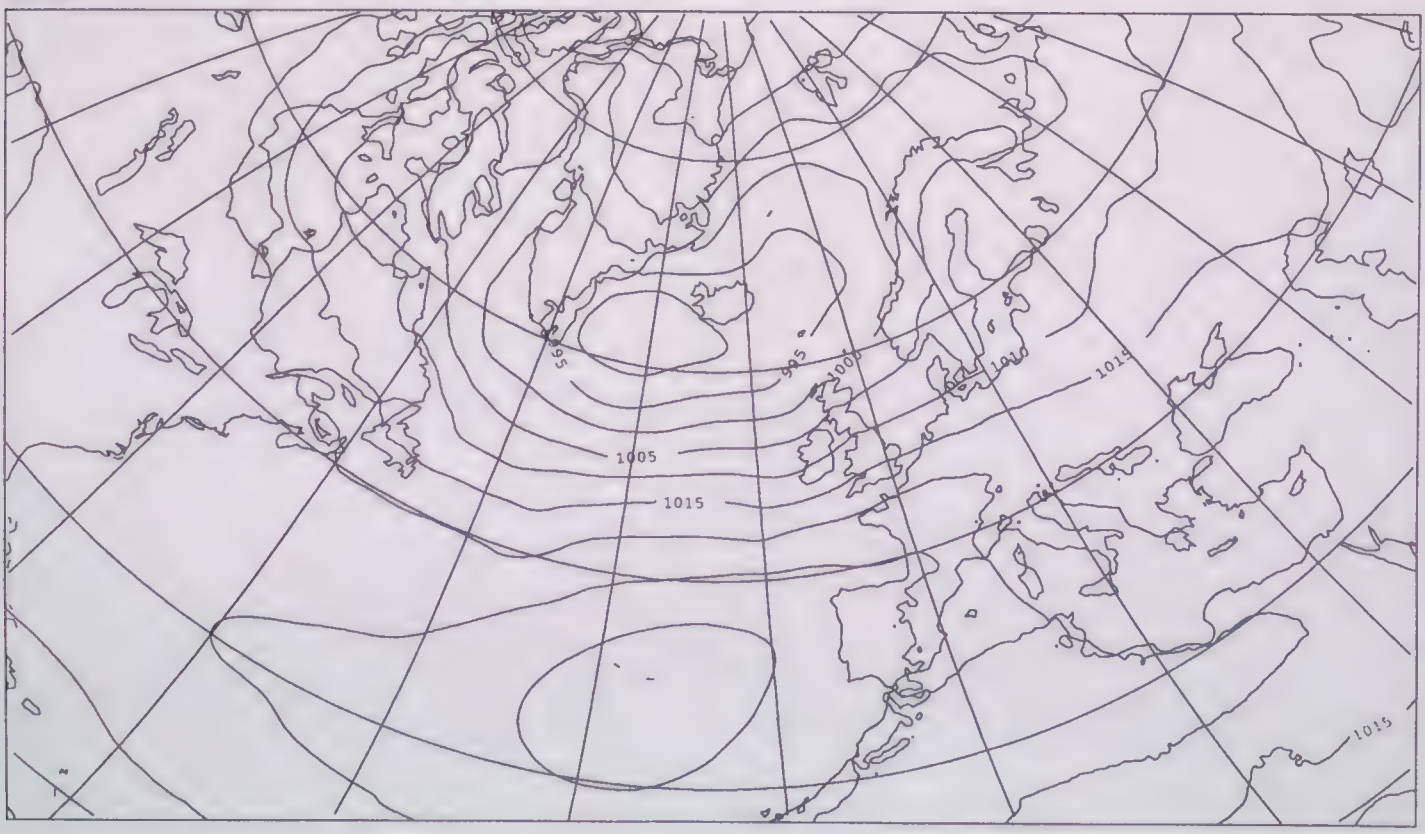
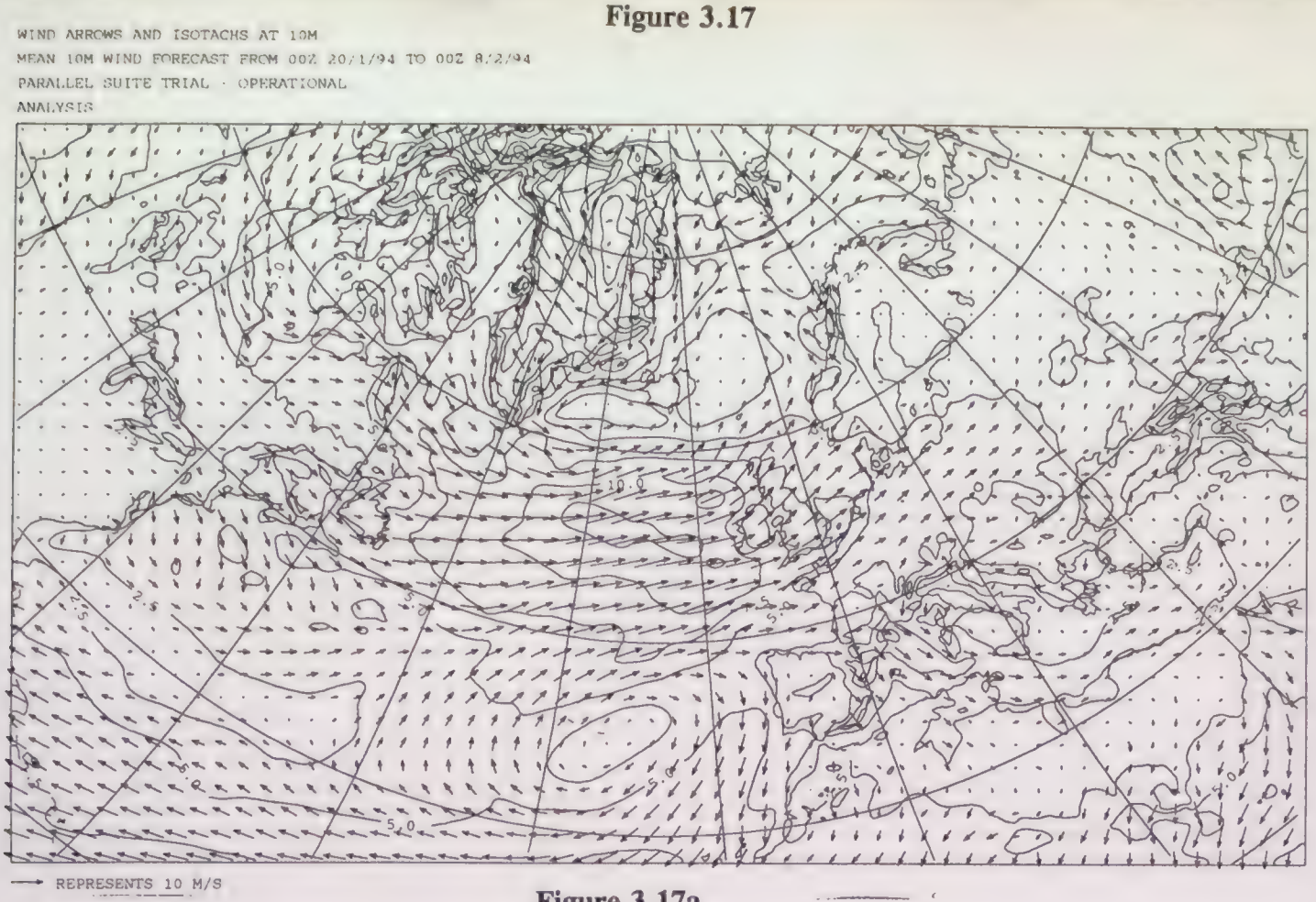
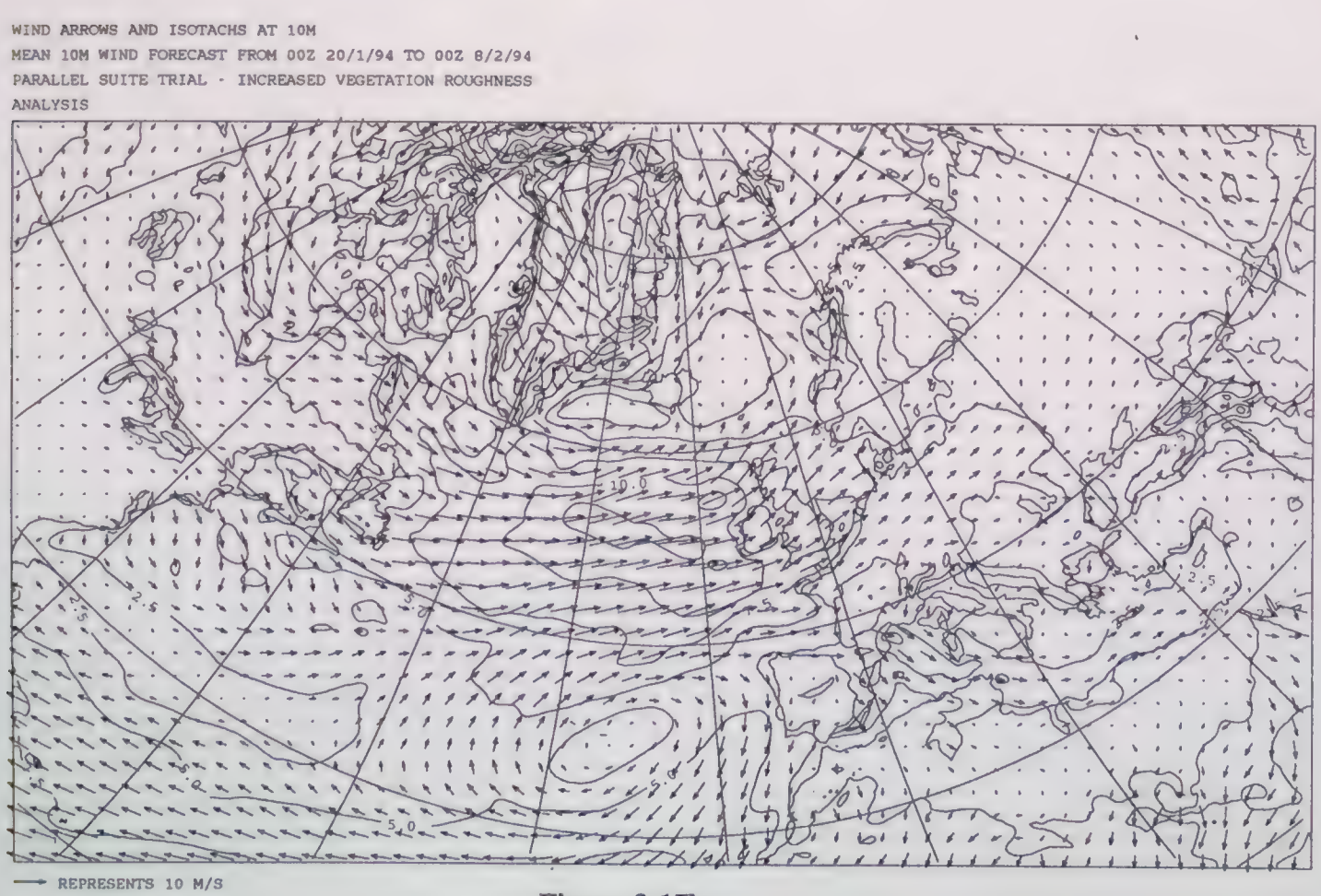



**Figure 3.16b**

## Figure 3.17




## Figure 3.17a




## Figure 3.17b

# Figure 3.18

MEAN SEA LEVEL PRESSURE DIFFERENCES
MEAN DIFFERENCE FROM 00Z 22/1/94 TO 00Z 10/2/94
TRIAL (INCREASED VEGETATION ROUGHNESS - OPERATIONAL)
T+24

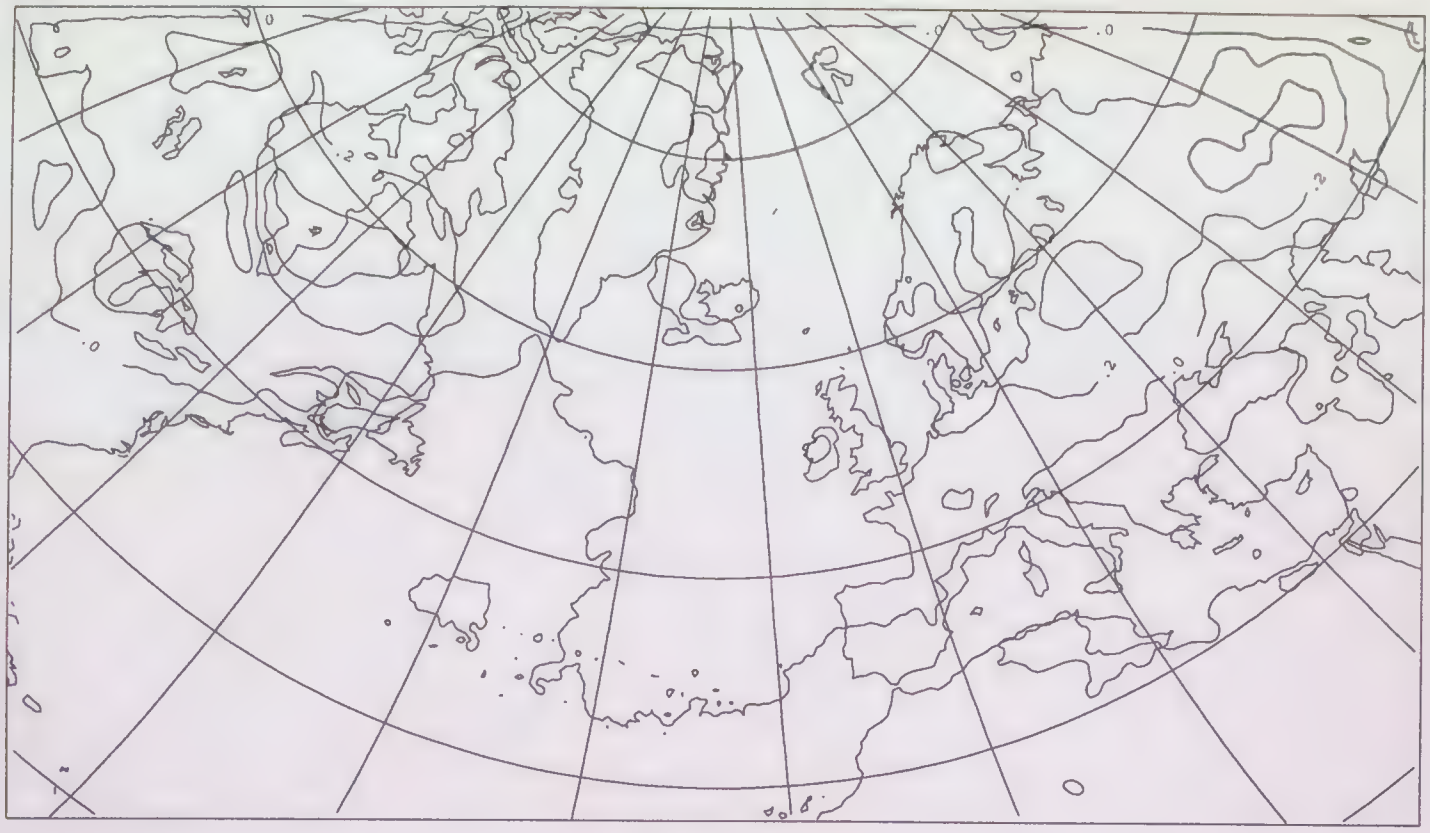
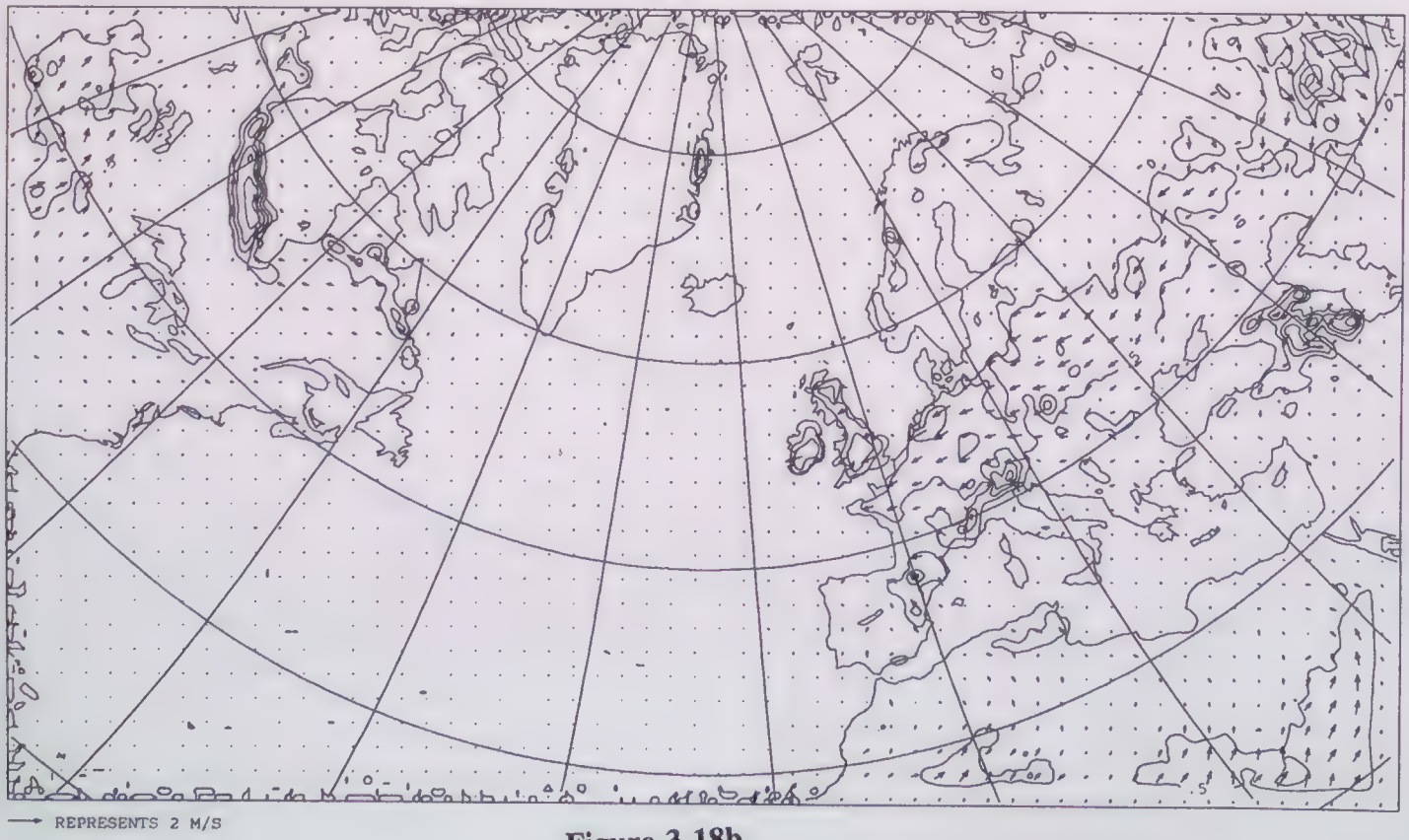


**Figure 3.18a**

10M WIND DIFFERENCES
MEAN DIFFERENCE FROM 00Z 21/1/94 TO 00Z 9/2/94
TRIAL (INCREASED VEGETATION ROUGHNESS - OPERATIONAL)
T+24



REPRESENTS 2 M/S

**Figure 3.18b**

# Figure 3.19

MEAN SEA LEVEL PRESSURE DIFFERENCES
MEAN DIFFERENCE FROM 00Z 22/1/94 TO 00Z 10/2/94
TRIAL (INCREASED VEGETATION ROUGHNESS - OPERATIONAL)
T+36

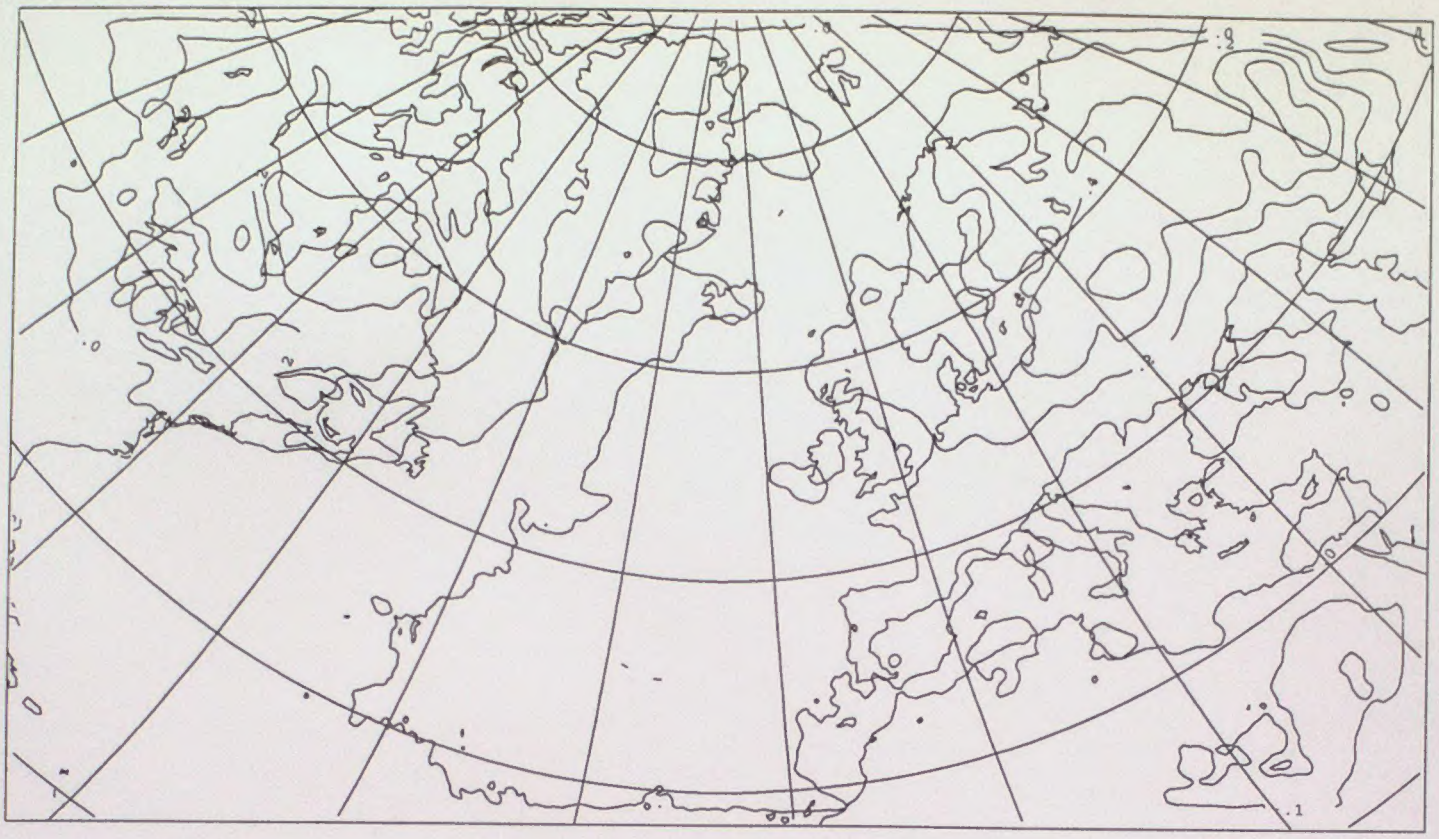


Figure 3.19a

10M WIND DIFFERENCES
MEAN DIFFERENCE FROM 12Z 21/1/94 TO 12Z 9/2/94
TRIAL (INCREASED VEGETATION ROUGHNESS - OPERATIONAL)
T+36

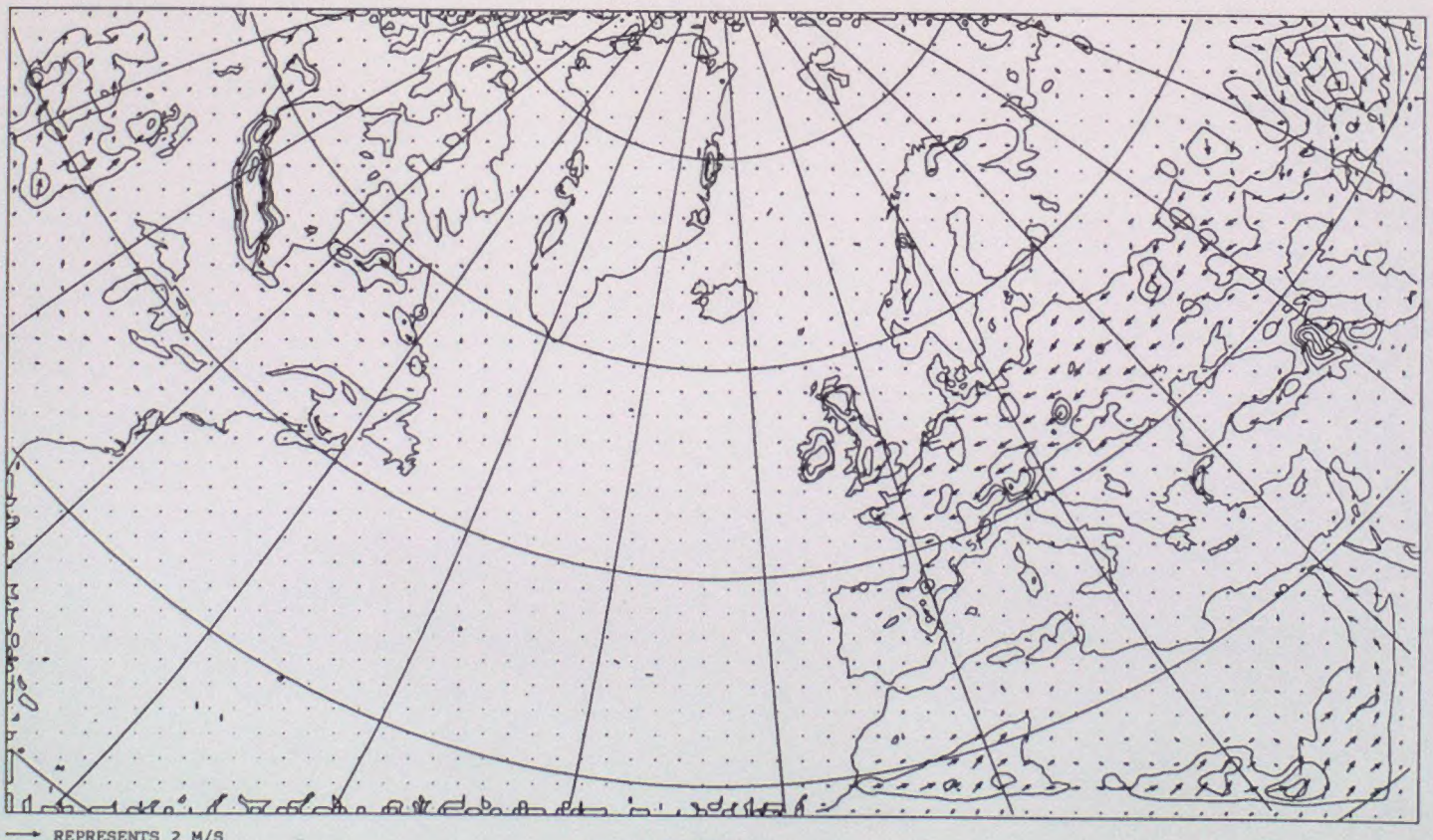



Figure 3.19b

MEAN SEA LEVEL PRESSURE DIFFERENCES
MEAN DIFFERENCE FROM 00Z 22/1/94 TO 00Z 10/2/94
TRIAL (INCREASED VEGETATION ROUGHNESS - OPERATIONAL)
T+48

**Figure 3.20**

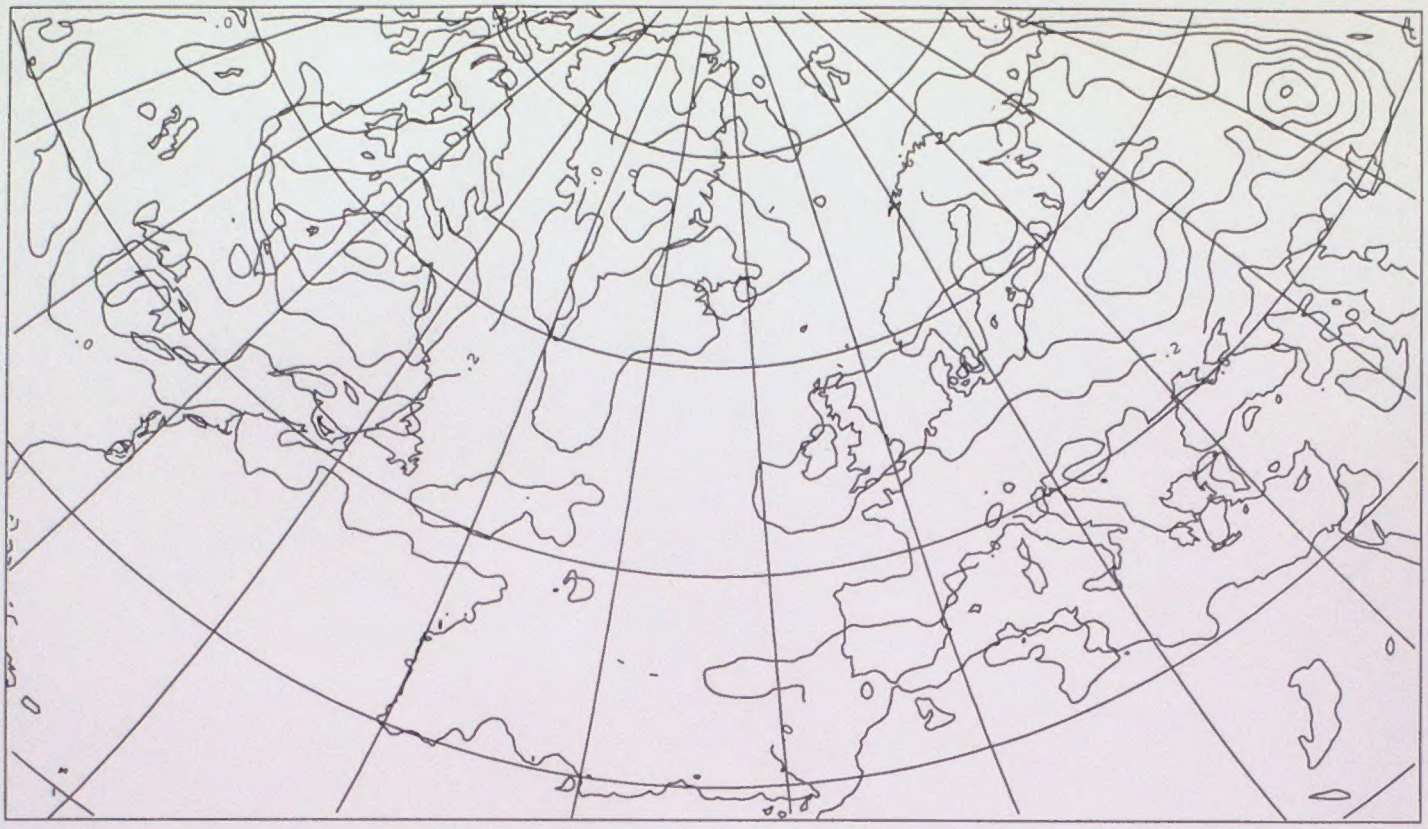
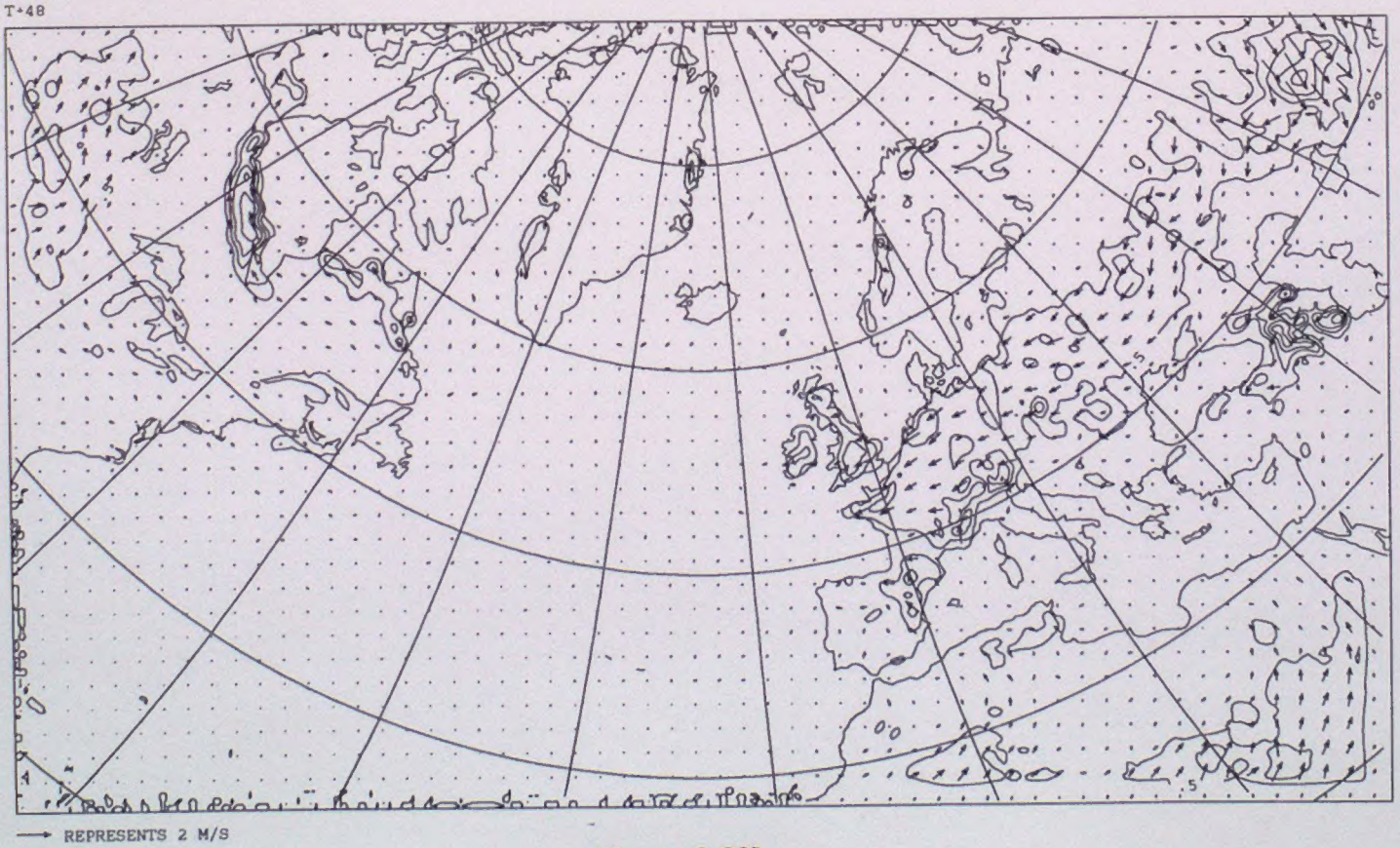


**Figure 3.20a**

10M WIND DIFFERENCES
MEAN DIFFERENCE FROM 00Z 22/1/94 TO 00Z 10/2/94
TRIAL (INCREASED VEGETATION ROUGHNESS - OPERATIONAL)
T+48



→ REPRESENTS 2 M/S

**Figure 3.20b**

MEAN SEA LEVEL PRESSURE
AVERAGE FROM 00Z 28/1/94 TO 00Z 10/2/94
PARALLEL SUITE TRIAL - OPERATIONAL
T+48 FORECAST

**Figure 3.21**

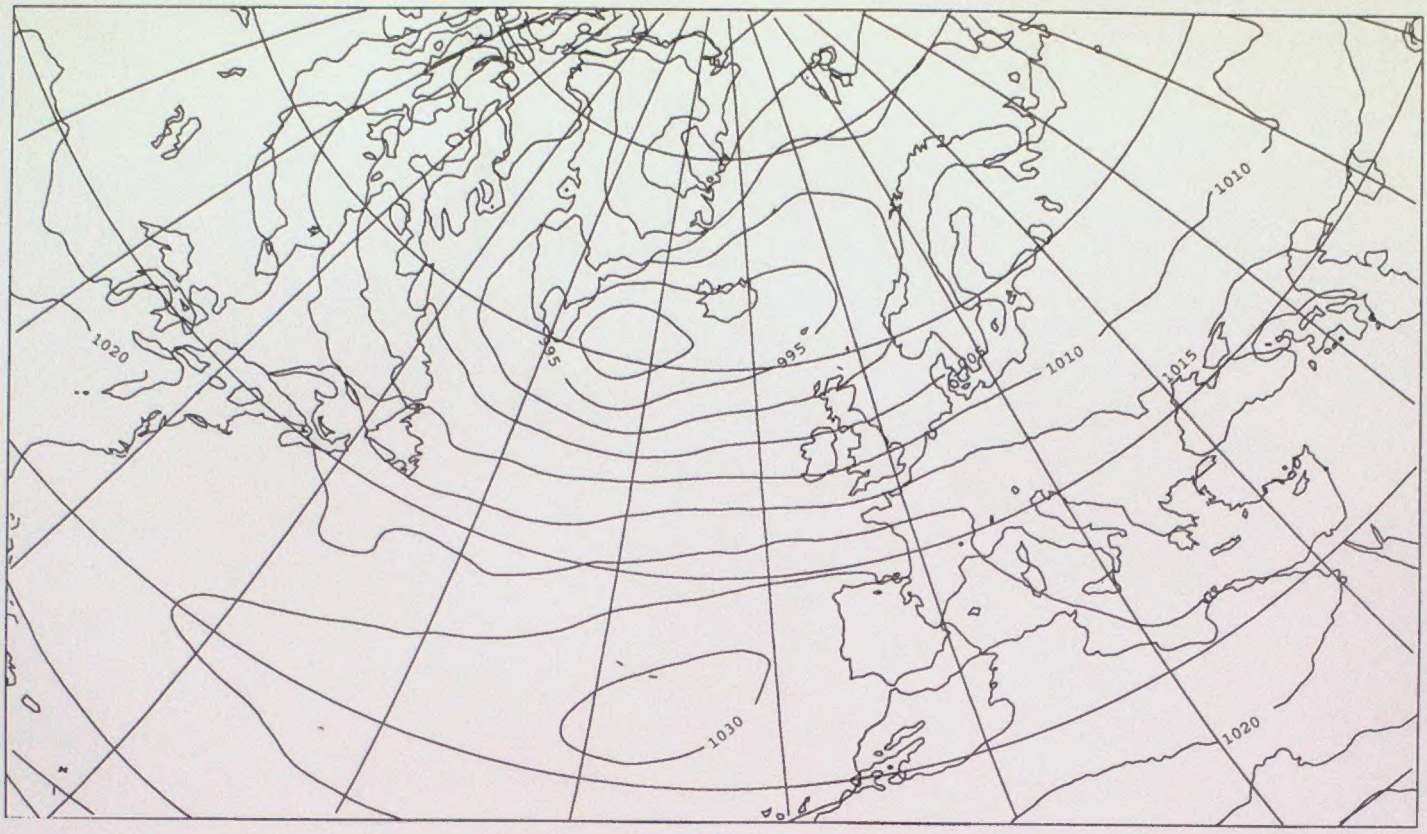



**Figure 3.21a**

MEAN SEA LEVEL PRESSURE
AVERAGE FROM 00Z 28/1/94 TO 00Z 10/2/94
PARALLEL SUITE TRIAL - INCREASED VEGETATION ROUGHNESS
T+48 FORECAST

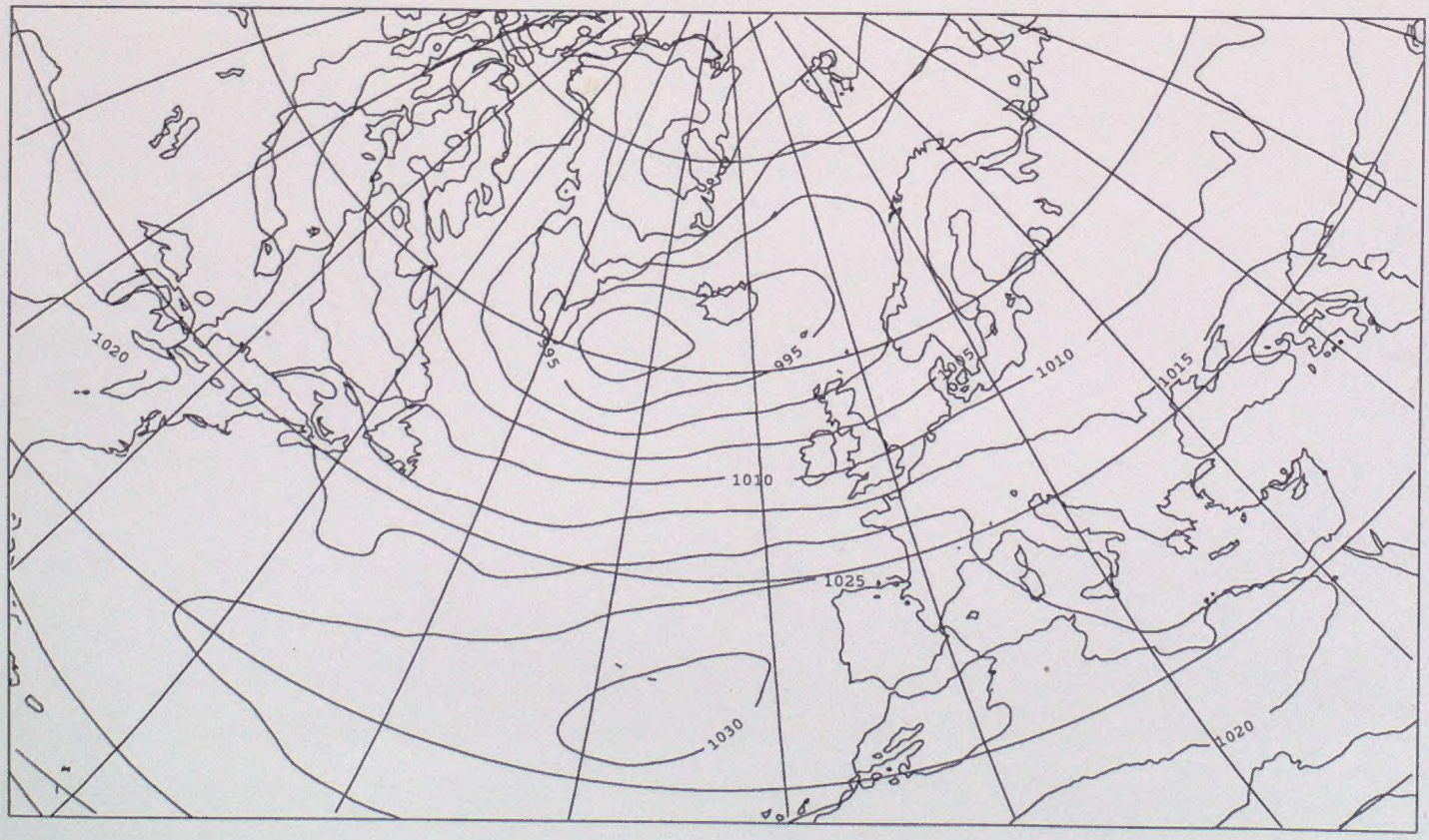
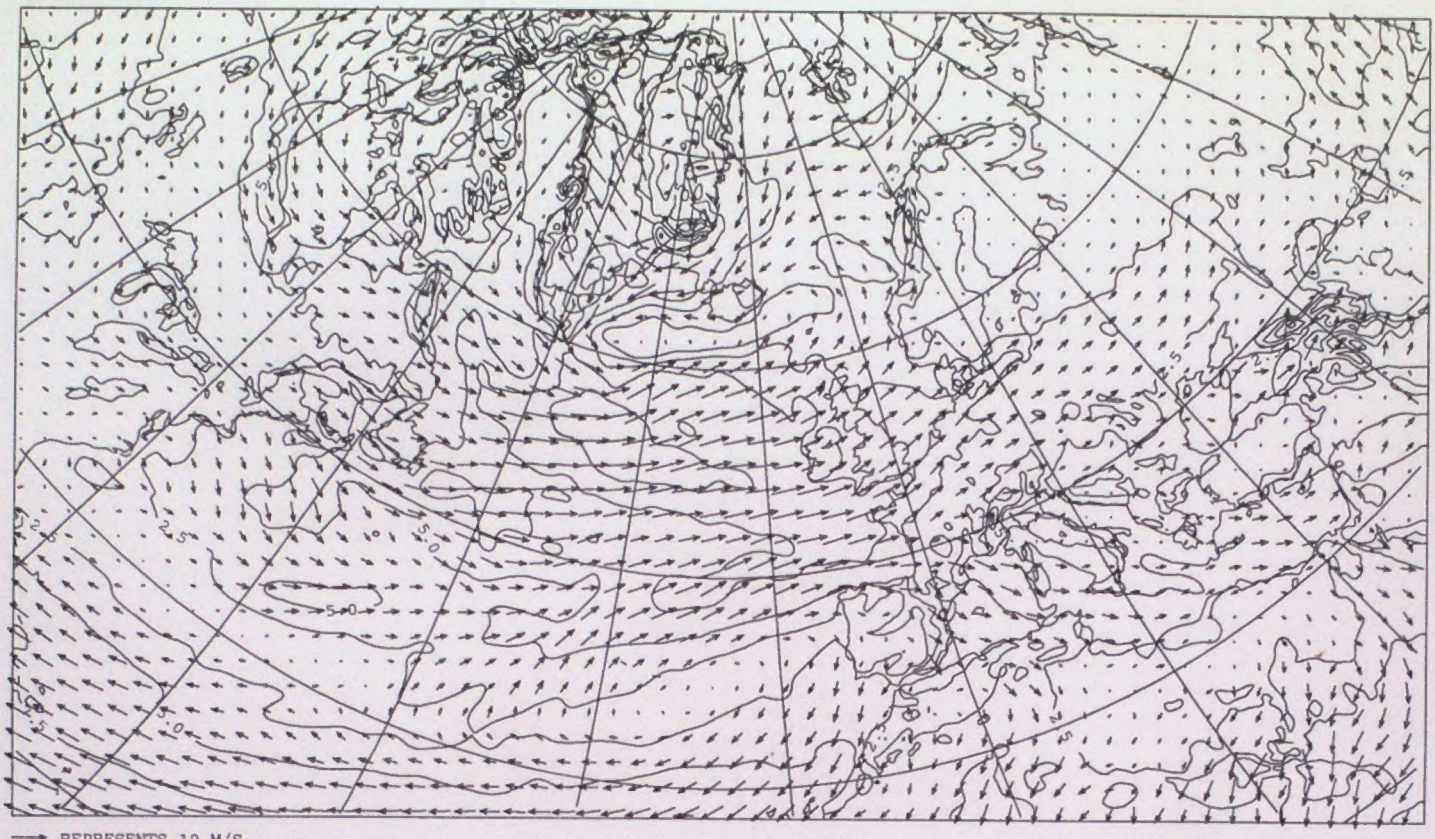



**Figure 3.21b**

# Figure 3.22

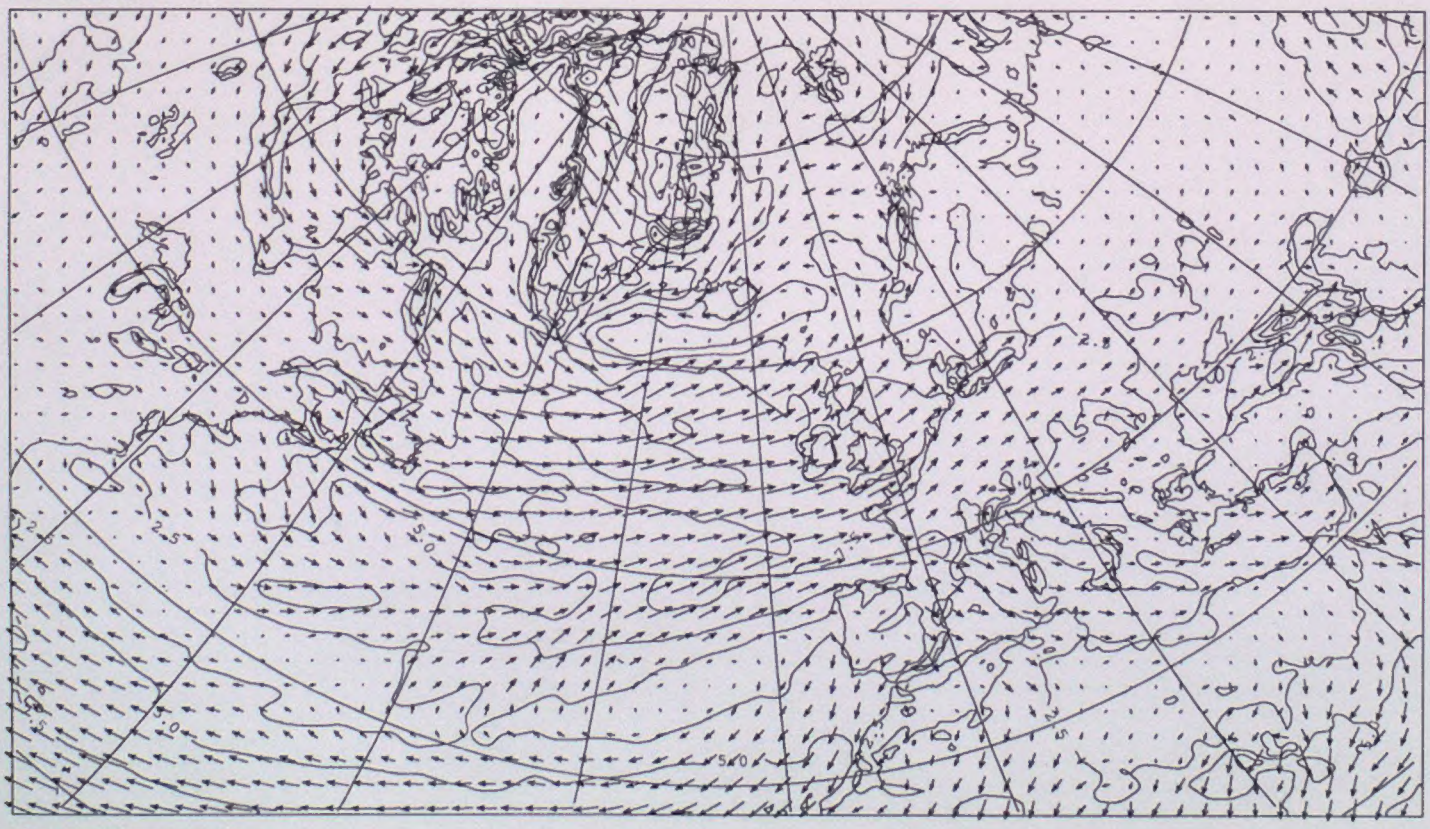
WIND ARROWS AND ISOTACHS AT 10M
MEAN 10M WIND FORECAST FROM 00Z 22/1/94 TO 00Z 10/2/94
PARALLEL SUITE TRIAL - OPERATIONAL
T+48 FORECAST




REPRESENTS 10 M/S

Figure 3.22a

WIND ARROWS AND ISOTACHS AT 10M
MEAN 10M WIND FORECAST FROM 00Z 22/1/94 TO 00Z 10/2/94
PARALLEL SUITE TRIAL - INCREASED VEGETATION ROUGHNESS
T+48 FORECAST




REPRESENTS 10 M/S

Figure 3.22b